BRACKET POSITIONING

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DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation titled **"THREE DIMENSIONAL EVALUATION OF ACCURACY OF BRACKET POSITIONING"** is a bonafide and genuine research work carried out by me under the guidance of **Dr. M. K. ANAND, M.D.S.,** Professor, Department of Orthodontics and Dentofacial Orthopaedics, Ragas Dental College and Hospital, Chennai.

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This dissertation is submitted to **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY,** in partial fulfillment for the degree **of MASTER OF DENTAL SURGERY in BRANCH V** - Orthodontics and Dentofacial Orthopedics. It has not been submitted (partially or fully) for the award of any other degree or diploma.

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Introduction

INTRODUCTION

Accurate bracket positioning forms the theoretical underpinning for fixed appliance therapy in orthodontics. Notwithstanding clinician skill along with distinct angulation and inclination values cut into the bracket, forced and unforced errors during direct bonding technique make realization of malocclusion correction a less successful one; not to mention time consuming. In an attempt to overcome the disadvantages of direct bonding procedure, many clinicians began to explore the indirect bonding technique first introduced by **Silverman et al[69].**

The indirect bonding system has many advantages: it makes the patients comfortable, facilitates easy reproduction of the bracket, provides easy over correction, allows for the control of in-out movements of the teeth, reduces the staff required for the treatment, and reduces treatment duration.

In **1982, Aguirre et al[1]** in their study comparing the two techniques demonstrated that in the upper arch the brackets bonded by the indirect technique were placed closer to the ideal height and angulation on canines whereas in the lower arch direct bonding proved to be more accurate with the mandibular second premolars. Although, neither direct nor indirect bonding was found to be 100 percent accurate, a bracket failure recording within 3 months of appliance placement showed indirect bonds had a smaller percentage of failure than direct bonds and it is eminent that indirect bonding procedure resulted in less chair side time**. Koo et al[46]. in 1999** found that, on average, indirect bonding was more accurate with regard to bracket height, with no significant difference between direct and indirect bonding for angulation and mesiodistal position. Similarly, **Hodge et al[34].** stated that the main advantage of indirect bonding over direct bonding is the reduction in the envelope of error in bracket position in each of the 3 orientations examined (vertical, horizontal and angular).

Contrary to the results documented in the above studies, **Zachrisson and Brobakken[80]** in 1978 reported that indirect bonding was associated with greater failure rate with direct bonding having an advantage over indirect with regards the closer fit of the bracket base to the tooth surface, removal of excess flash around bracket base and constant filling out of the bonding adhesive over the entire contact surface of the bracket.

Orthodontic literature reflects the on- going research with regards direct and indirect bonding techniques conducted with the assistance of recent imaging techniques like CBCT, that allow complete visualisation of tissues in three dimensions including the root of the tooth simply because accurate bracket positioning dictates the ultimate outcome of orthodontic treatment.

Aim and Hypothesis

AIM AND HYPOTHESIS

AIM

a) The primary aim of the present study is to assess the bracket positioning errors in vertical direction, horizontal direction, bracket angulation and adhesive thickness.

b) Secondary aim of the present study is to observe and evaluate the relationship between the total clinical crown height, marginal ridge to centre of the bracket and marginal ridge to FACC.

HYPOTHESIS

The null hypothesis of the present study is “there is a difference in the accuracy of bracket positioning between three-dimensional indirect bonding and conventional direct bonding technique”.

Objectives

OBJECTIVES

1. To compare the bracket positioning errors between direct and indirect-direct bonding groups from photos and models.

2. To observe the relationship between the marginal ridges, Centre of the bracket and FACC point and to fabricate the indirect-direct bonding trays with the help of CBCT, digital model and Mimics software.

Review of Literature

REVIEW OF LITERATURE

Lawrence f. Andrews[5] (1972) examined 120 casts of non-orthodontic patients with normal occlusion found six significant characteristics. He referred them as “6 keys to normal occlusion” and described their importance. The 6 keys gave importance to particular molar relation, crown angulation, crown inclination, absence of rotations, and absence of spaces and flat to mildly curved occlusal plane. Achieving the final desired occlusion was considered the purpose of attending to the six keys to normal occlusion

Elliott Silverman[69] (1972) Put forward that direct bonding system in orthodontics is a time saved technique which enables the orthodontist to spend more time on treatment procedures, And the ability to treat borderline cases as an one traction basis is the another advantage to band less orthodontics , so that the space occupied by the stainless steel band can be eliminated.

Elliot Silverman and Morten Cohen[67] (1975) introduced a new technique wherein brackets were fixed on to a cast with sticky glue. When set a transfer tray or bracket tray was fabricated that held the brackets. The teeth to be bonded were subjected to pumice prophylaxis and etching then the transfer tray with a UV light cured composite resin on the bracket bases was placed on the arch and cured with a UV light.

Elliot silverman and mortancohen[68] (1976) In their second article described a modification of their previous technique. A new material called “auto tach” was introduced instead of the UV light cured composite. Anauto touch self cured hydrophilic resin cement formulated for maximum penetration thebrackets were secured on to the cast with nuvatach, which is sticky glue material and a transfer tray is made after etching and drying the teeth to be bonded, autotach, which is a 2 paste system, is mixed on a cold slab and applied to the bracket bases on the transfer tray. Since the setting time for auto-tach is limited, time should not be wasted after the 2 pastes are mixed to insert the tray in to the mouth.

Zacharisson and brobakken[80] (1978) in this article they compared clinically direct vs. indirect bonding with different bracket types and adhesives.42 children were included in the study in the maxilla 24 quadrants were bonded directly and 16 quadrants were bonded indirectly. In the mandible 28 and 24 were the number of quadrants respectively. Results showed that failure rates were low for the direct bonded attachments and overall with direct bonding 6 of 243 and 28 of 201 with indirect bonding was the number of failures. The difference of 2.5 vs. 13.9% was statistically significant .The most number of failures was seen in the premolar region in both mandibular and maxillary arches.

Eugene L Dellinger[20] (1978) Conducted a study to determine the validity of the straight wire appliance concept. A plane called the HOL line, or horizontal line was established according to methods used by proponents of the straight-wire appliance. The tangents to the intersection of this plane at the labial or buccal surfaces of the teeth were measured. These measurements may be thought of as planes of surface adaptation (PSA). They appeared in a totally inconsistent and erratic manner and represented such great ranges that it is possible that present day straight-wire theory has little scientific basis. This study concluded that achievement of acceptable orthodontic results is possible with straight-wire therapy, with proper wire bending.

Michael Meyer[54] (**1978)**, the introduction of totally preadjusted appliances has had a significant impact on edgewise orthodontic treatment. It is important to understand the theoretical aspects of any technological improvement if it is to be used to advantage. On the other hand, theory cannot stand alone in a clinical discipline such as orthodontics. With this in mind, this article contains both theoretical considerations and practical clinical applications of preadjusted appliances.

Royce G Thomas [66]**(1979)** introduced a new technique that involved the formation of a custom base on the brackets. The technique involved application of concise or dynabond, which are chemically, cured resins on the brackets to secure tray was fabricated with vacuum formed tray material. The clinical procedure involve etching and drying of the teeth followed by application of concise or dynabond "sealant; universal resin part (a). On the teeth. The custom bases on the transfer tray were painted with liquid sealant catalyst resin part (b). The tray is then held in the mouth for one and half minutes .The author says this technique can provide a simple no rush atmosphere as no polymerization can occur till the two liquid sealants a and b come in contact with each other. Another advantage is that the unpredictable nature of the previously used glue or tape material during bonding of the brackets on the cast is eliminated

Aguirre, king and Waldron[1] (1982) assessed the accuracy of bracket placement and clinical failure rate comparing the indirect and the direct bonding technique. The indirect bonding procedure employed was the Thomas technique. 11 patients were included in the study .2 measurements were made from photograph of the teeth including vertical and angular measurements. Maxillary and mandibular arches were divided into hemi arches and one technique was used on each arch as decided by the flip of a coin. The direct technique was done with the help of visual inspection and the indirect technique involved ideally placing the brackets placed in the cast. A camera with jig attached having a rectangular wire at its end was used were the rectangular wire engaged the bracket for the photograph a vertical reference line was marked along the midline marker of the bracket and a horizontal plane in the rectangular wire. A vertical measurement linear was made along the vertical plane and the measurement lay between the points at which the horizontal plane intersected the vertical plane and the incisal and cuspal margin of the dental unit in question .The angular measurement was made on the angle formed by the mesio-occlusal margin of the vertical and horizontal planes were intersected as result there was no statistically significant difference in the vertical placement. Angular bracket placement showed statistically significant difference in the canines with indirect being more accurate. Bracket failures recorded three months after bonding showed 4.5 % for indirect and 5.3% for direct.

Alexander r g et al jco[3] (1983) relating efficient non extraction treatment with importance to bracket torque, recommended -5° torque on the mandibular incisors to resist anterior flaring of these teeth. The initiation of torque control with the initial flexible rectangular arch wire in the negatively torqued brackets will provide the control in positioning the mandibular anterior teeth-the key to a non-extraction case. Similarly -6° tip on the mandibular first molars aids distal movement of the molar crowns, which can create additional arch length. He recommended delaying mandibular arch bonding to prevent interferences in treatment as maxillary arch is treated

Alexander R G et al jco[2] (1983) concerned by the complicated appliance systems, to make treatment more convenient for the patient as well as for the orthodontist and staff developed an appliance called the vari-simplex discipline. "Vari" referring to the variety of bracket types used and "simplex" relating to the kiss principle (keep it simple, sir). The system evolved around five factors related to brackets: bracket selection, bracket height, bracket angulation, bracket torque, and bracket in-out pertaining to different malocclusion and treatment modalities.

Richard A. Hocevar[33] (1988) compared bond strength and fracture location for brackets bonded with the indirect procedure described by Thomas" versus conventional direct bonding.This in vitro study indicate that the indirect technique as described results in (1) reduced amount of resin flash, (2) diminished risk of voids that might weaken the bond and allow plaque accumulation, (3) minimal adhesive thickness, (4) sufficient bond strength, and (5) easier cleanup after debonding.

Peter v. Fowler in br j orthod[24] (1990) investigated the variability in the perception of ideal bracket location for the pre-adjusted edgewise appliance by the same clinician (intra-clinician variability) and between different clinicians (inter-clinician variability). Probable changes in crown inclination and root apex positioning, was also evaluated. Both intra- and inter-clinician variability/or the long axis of the clinical crown (lacc) angulation were large while very small variations occurred in the location of the long axis (la) point. Experience and training significantly reduced the variability in lacc angulation, but had little effect on the la point location.

NIGEL A. Fox[25] (1991) examined the shear bond strength of a conventional composite resin with the bond strength of a fluoride releasing composite and glass ionomer cement. The results obtained showed that the conventional composite had the highest mean bond strength. The results were also examines bond reliability rather than mean bond strength. It is likely that the two composites will behave in a similar manner in the clinical situation.

Nigel Geoffrey Taylor[27] **(1992)** studied the reliability of bracket positioning, using .022” straight wire brackets on anterior teeth of a typodont study model. In this study Slot angulation showed the largest variability and vertical bracket placement the least variability and concluded that the bracket angulation to be the most crtitical dimension for bracket positioning

Nasib balut et al[9] **(1992)** conducted a study to determine the accuracy of bracket placement with the direct bonded technique. Ten orthodontic faculty members bonded five cases of malocclusion using preadjusted orthodontic appliance on the models. The 50 sets of models were photographed were measured to determine vertical and angular discrepancies in position between adjacent bracket pairs from a constructed reference line. The upper anterior teeth and the upper and lower canines showed the most angular discrepancy. The most difficulty in vertical bracket placement was the upper second premolars, possibly because of the length of their clinical crowns which are sometimes short. A mean of 0.34 mm for the vertical discrepancies and a mean of 5.54° for the angular discrepancies are found in placement of the orthodontic brackets.

Bon Chan Koo[46] **(1999)** compared the accuracy of direct and indirect bonding techniques. In this invitro study nineteen sets of class ii malocclusion duplicated and divided in to three groups, one for ideal bracket placement, nine sets for direct and indirect bonding. Results of the study reveals that both direct and indirect bonding techniques failed to execute ideal bracket placement. Overall, indirect bonding showed better bracket placement in bracket height.

Anoop sondhi[72] **(1999)** has developed a new resin for indirect orthodontic bonding. Also, indirect bonding has the advantages of 1. Precise bracket placement 2. Optimizing the use of doctor's time 3. Avoiding band fitting on posterior teeth 4. Eliminating the need for separators.

Reiner et al [54(]**1999)** major effort is put into the design of brackets to accomplish an optimal completion of orthodontic treatment with respect to 1st, 2nd, and 3rd order corrections. Because such brackets are standardized, the intra individual variation of the teeth is not taken into consideration. The influence of vertical bracket displacement on 1st and 3rd order corrections was studied on the plaster models, including all teeth from central incisors to first molars, of 28 young persons. The facial contours were evaluated at the mesial, central, and the distal aspect of the bracket. The contours were calculated with the formula of a parabola, and the fit was found sufficient. Inter tooth variation was extreme, the biggest curvature was found among the first mandibular molars. The variation was also marked between

MCLAUGHLIN R.P and BENNETT J.C in JCO[65] **(1999)** took into consideration several factors such as gingival concerns, incisal and occlusal concerns and crown length concerns which were overlooked by Andrews in his concept of straight wire appliance. This led to recommendation of a theoretical bracket placement chart which eliminated the above mentioned concerns for achieving better aesthetics and minimizing vertical errors in bracket positioning leading to unwanted delays resulting due to repositioning of brackets.

Larry .W. white[49] (1999) stated that the hot glue matrix offers a reliable and inexpensive method for transferring accurately placed bracket to the teeth

R Bibb, P Freeman, R Brown et al[11] (2000) The aim of there investigation is to identify the problems that occurred during scanning for the design and manufacture of facial prostheses. The scanner used in this study was mainly an optical system of fringe pattern of white light and digital camera technology to capture approximately the surface of the object. Various issues were approached by this scanning Methods:1. Preliminary trial of facial scanning 2. Scanning a surgical subject 3. Prosthesis manufacture.The accuracy of the scan data was 0.05mm and the accuracy of the model was +/- 0.1mm. At last they say that these techniques may be a valuable aid to shaping and positioning the prosthesis based on the clinician's skill and knowledge.

Sean k. Carlson[14] (2001) described in detail a 5 step protocol for assessing and correcting bracket-positioning errors, achieving crown and root alignment, decreasing treatment time and improving final treatment result. These 5 steps included initial bracket positioning, primary expression of bracket prescription and position, the reset evaluation involving both a clinical and a radiographic evaluation, scheduling the reset appointment with adequate time for debonding, rebonding, and rebanding, and finally, secondary expression and finishing.

Kazuya Watanabe et al and Masatada Koga et al[45] in AO (2001) conducted a study to obtain basic data on bracket designs for the Asian patient by measuring relative to the occlusal plane by the Andrews' method using Setup models of 125 Japanese orthodontic patients. They reached the following conclusions; No difference was observed in crown angulations. Crown inclinations of the mandibular central and lateral incisors and canine were greater in the Class II setup with similar Maxillary molar offset

Yi GK, Dunn Wl[28] (2003) the purpose of this study was to compare the shear bond strength of orthodontic brackets bonded to teeth with either an indirect bonding technique or a new adhesive resin or a direct bonding technique and a light-activated adhesive. Fifty-four extracted premolars were mounted in acrylic blocks and randomly divided into 2 groups. In one group, orthodontic brackets were bonded to premolars with an indirect bonding adhesive system; in the other, brackets were bonded with the direct method. Seventy-two hours later, the brackets were placed in a testing machine and subjected to a shear force with a crosshead speed of 1 mm/minute. There was no significant difference between groups. Under the conditions of this study, no evidence suggests a difference in shear bond strength of orthodontic brackets bonded to tooth enamel, whether they are bonded with the direct or indirect technique.

P. G. Miles[55] (2003) compared and evaluated the clinical failure rates of the chemically-cured composite bonding resins Sondhi Rapid Set (SD) and Maximum Cure (MC) when used in an indirect bonding technique. Group 1 had the maxillary right and mandibular left quadrants indirectly bonded using SD adhesive, while the contralateral quadrants were bonded using MC adhesive. Group 2 had the opposite sides bonded to Group 1. Both chemically-cured adhesives (SD and MC) examined in this study were suitable for the indirect bonding of brackets. When comparing the two chemically-cured adhesives the SD adhesive had a significantly higher number of breakages than the MC adhesive. When comparing the two chemically-cured adhesives in each arch, the SD adhesive had a statistically significantly higher number of breakages than the MC adhesive in the mandibular arch only.

Hodge t m et al[34] (2004) performed a prospective, randomized controlled study using a split mouth design to compare and determine the accuracy of direct or indirect bracket placement. 26 patients were selected and labial surfaces of their upper and lower arch teeth were bonded using mbt™ pre-adjusted edgewise appliance randomly with either direct or indirect method. All brackets were photographed before and after bond-up and measured from tracings to determine positional differences.There was no significant difference between the mean errors produced by the two methods of bracket placement. The range of error in the three directions assessed was greater for direct than indirect placement.

Arndt Klocke[44] (2004) this study was to quantify the bond strengths of indirect bonding techniques and adhesives with a custom base of the bracket. Different types of custom base composites (light-cured, chemically cured, and thermally cured) were investigated in combination with chemically cured sealants. In this in vitro investigation, stainless steel brackets were bonded to 100 permanent bovine incisors using the Thomas technique, the modified Thomas technique, and light-cured direct bonding for a control group. The following five groups of 20 teeth each were formed: (1) modified Thomas technique with thermally cured base composite (Therma Cure) and chemically cured sealant (Maximum Cure), (2) Thomas technique with thermally cured base composite (Therma Cure) and chemically cured sealant (Custom I Q), (3) Thomas technique with light-cured base composite (Transbond XT) and chemically cured sealant (Sondhi Rapid Set), (4) modified Thomas technique with chemically cured base adhesive (Phase II) and chemically cured sealant (Maximum Cure), and (5) control group directly bonded with light-cured adhesive (Transbond XT).Both the original (group 2) and the modified (group 1) Thomas technique were able to attain bond strengths comparable to the light-cured direct bonded control group.

Hassan Z. Movahhed[57] (2005) in this study they investigated the bond strength of orthodontic brackets bonded with a light-cured resin RRGIC and a composite adhesive each used in combination with a self-etching primer at different time intervals, and to assess when arch wires could be placed after bonding and examined the fracture site at debond with the two different bonding systems.

Eighty freshly extracted human premolars were used. Twenty teeth were arbitrarily assigned to each of four groups: (1) brackets bonded with Transbond XT with a Transbond Plus etching primer and debonded within 5 minutes; (2) brackets bonded with Fuji Ortho LC and debonded within 5 minutes; (3) brackets bonded as for group 1 and debonded within 15 minutes; (4) brackets bonded as for group 2 and debonded within 15 minutes The present findings designate that brackets bonded with either Transbond XT in combination with Transbond Plus etching primer and Fuji Ortho LC had sufficient bond strength at 5 minutes and were even stronger 15 minutes after initial bonding.

Garino F, Garino GB[26] (2005) presenting a computer-aided solution to orthodontic indirect bonding, allowing accurate positioning of straight-wire brackets based on a virtual occlusal set-up resulting from the treatment plan. Computer-aided indirect bonding was applied in two cases: a Class II patient in the permanent dentition, crowding, rotation of upper and lower bicuspids and a Class I patient in the permanent dentition with already extracted 1.4, 2.4, 3.4, 4.4, severe crowding, rotation, arch form reduction. Speed brackets were utilized in both cases. In the first case the brackets' starting position on the patient corresponds to the final position on the virtual occlusal set-up. In the second case the resulting occlusion at the end of treatment corresponds to the final occlusion on the virtual occlusal set-up. The computerized tools employed in the process enabled precise bracket placement on the stone model. An algorithm from the virtual set-up is the determinant for the precision. Computer aided indirect bonding is a method of placing brackets precisely.

Brandon James Linn[50] (2006) in this study they compared the shear bond strength and the sites of bond failure for brackets bonded to teeth, using two indirect-bonding material protocols and a direct-bonding technique. Sixty extracted human premolars were collected and arbitrarily divided into three groups. The direct-bonded group (group 1) used a light-cured adhesive and primer (Transbond XT). One indirect-bonded group (group 2) consisted of a chemical-cured primer and light-cured adhesive (Transbond XT), while the other group (group 3) used a light-cured primer (Orthosolo) and adhesive (Enlight LV). Forty hours after bonding, the samples were debonded. Results showed no significant difference in mean bond strength between groups. For each tooth, an Adhesive Remnant Index (ARI) score was determined. Group 2 was found to have a considerably lower ARI score compared with groups 1 and 3. In addition, Pearson correlation coefficients indicated no strong correlation between bond strength and ARI score within or across all groups.

Cevidanes L.H.S et[51] al in AJODO (2006) affirmed that Three-dimensional (3D) imaging techniques can provide better valuable information to clinicians and researchers including initial diagnosis and superimpositions and also for assessing growth, treatment changes, and stability. Furthermore, relationships of soft tissues and the airway can be assessed in 3 dimensions.

Stevens D. R et al[74] AJODO (2006) compared standard plaster models with their digital counterparts made with emodel software (version 6.0, GeoDigm, Chanhassen, Minn) for the analysis of tooth sizes and occlusal relationships (the Bolton analysis and the peer assessment rating (PAR) index) and their components using Dental casts from 24 subjects with 8 malocclusion types. The authors concluded that the preliminary results did not indicate that digital models would cause an orthodontist to make a different diagnosis of malocclusion compared with plaster models; digital models are not a compromised choice for treatment planning or diagnosis

Whetten J. L et al[78] in AJODO (2006) to validate digital models as an alternative for conventional plaster models analyzed ten sets of records of Class II malocclusion subjects were used for treatment planning by 20 orthodontists on 2 separate occasions. Digital models were used to evaluate the patients at 1 session and plaster models were used at the other session. Treatment recommendations were scored and compared for agreement. There was no statistical difference in intra-rater treatment-planning agreement for Class II malocclusions based on the use of digital models in place of traditional plaster models. Digital orthodontic study models are a valid alternative to traditional plaster study models in treatment planning for Class II malocclusion patients.

John t. Kalange[38] (2007) discussed the pertinent issues relative to the development and utilization of indirect bonding. Relatively complicated process, bracket positions are established, archwire geometry is configured, and custom indirect bonding trays from the setup can be constructed. Ceramic brackets could not be exposed to such heat. If transparent tray used light cure resin unit can be used.

Anoop Sondhi[73] (2007) gave a new method for effective and efficient indirect bonding of orthodontic brackets. The custom adhesive bases are easily formed with transbond xt or apc brackets, and the indirect bonding is accomplished using a new resin. Bond strength has proven to be excellent, and the author and others have used this system for the indirect bonding of complete dental arches, from second molar to second molar, on pediatric, adult, and orthognathic patients.

Terry a. Guenthner[31] (2007) states that (1) Practice efficiency could be improved, (2) Technique insensitive, (3) Paying attention to the precision and details Indirect bonding had the advantages include (1) Less chair time, (2) Just arch wire changes and adjustments, (3) better ease of work, (4) less physical stress, and (5) improved productivity. Author considered that indirect bonding to be a useful and efficient approach that improves the results of the treatment.

Masatada koga[45] (2007) described quick indirect bonding technique using double silicon bracket transfer tray. This tray is rigid and dimensionally stable when placed on the teeth and accurately reproduces bracket position for each tooth. Easy to visualize the bracket position during curing the composite because of the clear silicone materials. However the disadvantage is high cost and requires a rapid and efficient application of two silicone materials. He concluded that the position of the brackets placed on working models are reproduced on tooth surfaces with a very high level of accuracy. Causes of the errors may include the use of an excessive amount of soft silicone, inadequate thickness of the hard silicone, and because of the application of excessive pressure distortion of tray on the tooth surface occurs.

David armstrong et al[7] ejo (2007) conducted an experiment to compare the accuracy of bracket positioning between two methods of bracket placement locating the bracket at the centre of the clinical crown (cc) and at a measured distance from the incisal edge (me). Nineteen experienced orthodontists bonded 20 brackets on one typodont using the cc method and 20 brackets on another typodont using the memethopre-adjusted straight-wire brackets (victory mbt). The teeth were removed from the typodont and photographed for imaging analysis. A significant vertical difference between the cc and me methods, with the method more accurate vertically but no significant differences for mesiodistal errors were noted. It is suggested that bracket bonding guided by measuring the distance from incisal edge may result in improved placement for anterior teeth.

Elliot M. Moskowitz et al Sem in Ortho[56] (2007) modified the Thomas technique of indirect bonding of bracket, He used flexible inner tray made of vinyl polysiloxane impression material and a vacuum formed essix retainer to cover the inner tray encase the brackets. He claimed that thermal cured composite provided a virtually unlimited working time for the placement of orthodontic attachments including high inevitability and highly reproducibility.

S. Thomas Deahl[19] (2007) The purpose of this study was to compare the bond-failure prevalence, numbers of appointments, and treatment times between direct and indirect bracket bonding for patients treated in private orthodontic practices. A convenience sample was collected from 11 orthodontic offices; 5orthodontists (772 patients) used a direct bonding technique, and 6 (596 patients) used indirect technique. In total, they examined 29,963 brackets in 1,368 patients. Bond failures were recorded by tooth number and by patient during 10 consecutive practice days. This practice-based study showed no difference in the failure rates, total treatment times and numbers of appointments between direct and indirect bonding techniques.

Larry White et al[48] (2007) described the advantages of accuracy and low cost,but additionally offers clinicians a method that allows them to bond one by one,while individual pressure on each tooth.He used the Aleenes Tacky glue then placed bracket on the cast instead of candy.

Thicket et al[76] (2007) to show how three pre-adjusted orthodontic bracket systems (Andrews, Roth and MBT) vary drastically in their ability to control tooth position and appearance. A bracket’s in-built prescriptions of torque, tip and inout need check both at treatment outset, and as teeth respond to orthodontic forces. Modifications to bracket position and prescription can maximize the potential from the pre-adjusted appliance: 1. Bracket inversion; 2. Placement of the contra lateral bracket on the tooth; 3. Use of alternative bracket systems—Andrews versus Roth versus MBT.

Rangel F.A[63] in AJODO (2008) through a technical report offered a viability study of the integration of a digital dental cast into a 3D facial picture. For the integration, 3 digital data sets were constructed: a digital dental cast, a digital 3D photograph of the patient with the teeth visible, and a digital 3D photograph of the patient with the teeth in occlusion. By using an integrated closest point algorithm, the 3 data sets were matched to place them in the correct anatomical position. After matching the 3 data sets, a 3D digital model with the dental cast visible through the transparent picture of the patient’s face. It is possible to make a data set of a patient’s face with the dentition positioned into this 3D picture. However, Future research needs to establish the value of this 3D fused data set in orthodontic diagnosis and treatment planning.

Seong-Hun Kim eta al[43] in WJO (2008) described and demonstrated a clinical application of a new surgical guide system that used cone-beam computed tomography (CBCT) images. Acquisition slices for the posterior maxilla were 0.15 mm in panoramic mode of PSR 9000N model (Asahi Roentgen, Kyoto, Japan), an implant-positioning program (SimPlant), and stereolithography to make a surgical guide for accurate placement of orthodontic mini implants. The surgical guide was easily placed intraorally and permitted simple and rapid placement of the mini-implant. The site of the implant placement was accurate, while the vector varied slightly from the planned vector. Improvements in the CBCT resolution and laser-scanning technology are likely to eliminate any discrepancies.

Birnie D in Sem Orthod[12] (2008) discussed in detail the advantages of Passive ligation created by the Damon self-ligating bracket system. He reviewed the various types of bracket designs, the selection of bracket in relation to various types of malocclusion and the various steps in treatment of malocclusion with Damon brackets.

Mark Joiner et al[37] in AJO (2010) described a modification of Kalange’s technique that was believed improve accuracy and repeatability of indirect bonding using 2 bow compasses and 3 mechanical pencils. Using the compasses, two dots are placed on each of the posterior teeth and the dots are connected. He suggested mandibular canine be placed 1 mm rather than 0.5 to 0.75 mm to that of the mandibular premolars.

Hend Mohammed El-Zanaty et al[23] AJODO (2010) compared the accuracy of dental measurements taken using calipers on plaster dental casts and those formed from computed tomography scans of the dentition with a(3DD,Biodent,Cairo,Egypt) dental measurement program. He concluded that 3DD can be an alternative to conventional stone dental models.

Matthew Israel Et Al[35] Ao (2011) tested the differences in the accuracy of bracket placement completed by orthoCADiQ indirect bonding (idb) and that of an in-house fabricated idb system. Forty-six sets of models were randomly divided into two sample groups. Half of the models had their bracket positions selected by orthoCAD, while remaining by faculty and residents in a university orthodontic department. The quality of intra-arch dental alignment at the end of simulated orthodontic treatment were measured using the objective grading system (ogs) originally designed by the american board of orthodontics. No statistical difference was found between total scores or any of the components evaluated. However, OrthoCADiQ produced a wide range of ogs scores indicating a lower level of consistency than expected and was significantly less successful at achieving proper alignment and buccolingual inclination of the upper first premolars and properly angulating the lower lateral incisors. OrthoCADiQ did not offer a system that can position orthodontic brackets better or more reliably than traditional indirect bonding techniques.

Kyoung-Hui Son[71] (2011) this article is to bring in a new virtual orthodontic treatment (VOT) system, which can be used to construct (3D) virtual models, establish a 3D virtual setup, for placement of the virtual brackets at the pre-determined position, and fabricate the transfer jig with a customized bracket base for indirect bonding (IDB) using the steriolithographic technique. Concluding, The virtual orthodontic treatment system produced an acceptable treatment result.

Lahcen Ousehal[60] (2011) study was conducted in ten models of natural maxillary teeth they compare the accuracy of bracket placement between two direct bonding instruments: the pole-like Bracket Positioning Gauge and the star-like Bracket Positioning Gauge. Our results have shown that: the star-like Bracket Positioning Gauge is more precise in placing brackets vertically, whereas the pole-like Bracket Positioning Gauge allows a better angulation of the bracket. Considering each tooth separately, there is no statistically significant difference between the two positioning gauges, except that the star-like gauge gives better results in bracket's height for the second premolar and the canine, whereas the pole-like gauge allows for a better positioning and a better vertical angulation of the brackets for the lateral incisor. For the mesiodistal position there is no statistical significant difference between these two gauges.

Domenico Dalessandria[17] (2012) evaluated the indirect braces bonding technique and conventional direct-bonding technique for localized enamel etching and adhesive application that helps to reduce plaque accumulation and demineralization. Thirty patients were bonded with a split-mouth approach: two randomly selected opposite quadrants were used as the test sides and the other two as control sides. During the first 6 months, the plaque presence around the braces was recorded monthly according to a plaque accumulation index (PAI), as was the presence of demineralization. PAI values were measured at each of the four bracket sides for every bonded tooth and they found that during the first 4 months after brackets placement, this indirect bonding protocol allowed for significant reduction in plaque accumulation around the braces and reduced onset of white spots during the orthodontic treatment.

Magdalena Kasparova[40] (2013), compared traditional plaster casts, digital models and 3D printed copies of dental plaster casts based on various criteria .concluded that it is possible to construct digital data to obtain 3D printed models and it is accurate.

Jefferson et al[36] (2013) this study assessed the time spent for direct (DBB - direct bracket bonding) and indirect (IBB - indirect bracket bonding) bracket bonding techniques. The time length of laboratorial (IBB) and clinical steps (DBB and IBB) as well as the prevalence of loose bracket. Seventeen patients with a mean age of 21 years, requiring orthodontic treatment were selected for this study. A total of 304 brackets were used. The same bracket type and bonding material were used in both groups. Data were submitted to statistical analysis by Wilcox on non-par considering the total time length; the IBB technique was more time-consuming than the DBB. However, considering only the clinical phase, the IBB took less time than the DBB. There was no significant difference for the time spent during laboratorial positioning of the brackets and clinical session for IBB in comparison to the clinical procedure for DBB metric test at 5% level of significance. The IBB can be suggested as a valid clinical procedure since the clinical session was faster and the total time spent for laboratorial positioning of the brackets and clinical procedure was similar to that of DBB. In addition, both approaches resulted in similar frequency of loose bracket.

Dale A. Nichols[58] (2013) evaluated the placement of orthodontic brackets at different times by various orthodontists Using cone-beam computed tomography and computer-assisted modeling software. Five orthodontists with experience in indirect bonding were selected to place brackets on 10 different casts at 3 time periods (n 5 30 per orthodontist). Each participant completed an initial indirect bonding setup on each cast; successive bracket placements were completed twice at monthly intervals for comparison with the initial setup. The casts were scanned using an iCAT cone-beam computed tomography scanner and imported into Geomagic Studio software for superimposition and analysis. The scans for each time period were superimposed on the initial setup in the imaging software, and differences between bracket positions were calculated. For each superimposition, the measurements recorded were the greatest discrepancies between individual brackets as well as the mean discrepancies and standard deviations between all brackets on each cast.It can be concluded that when orthodontists select bracket positions for a patient, they are consistent in selecting the same positions at future times. When different bracket positions are selected, the maximum difference at any point will tend to be less than 1.25 mm.

Ana E. Castilla[16] (2014) compared bracket transfer accuracy of five indirect bonding (IDB) techniques. Five IDB techniques were studied: double polyvinyl siloxane, double vacuum-form, polyvinyl siloxane vacuum-form, polyvinyl siloxane putty, and single vacuum-form. Brackets were bonded on 25identical stone working models. IDB trays were fabricated over working models to transfer brackets to another 25 identical stone patient models. In the working and patient models the mesiodistal, occlusogingival, and faciolingual positions of each bracket were measured using digital photography and calipers. Overall differences in bracket position were relatively small, silicone based trays had consistently high accuracy in transferring brackets, whereas methods that exclusively used vacuum-formed trays were less consistent.

Anna Menini[53] (2014) investigated the effectiveness of indirect bonding technique by evaluating the number of bond failures which occurred during treatment. Fifty-two patients were selected and divided into two groups: group A (33 patients) bonded with the direct technique and group B (19 patients) bonded with the indirect technique. The number and date of bracket failure were recorded for over 15 months. No statistical significant differences were found in the total bond failure rate between direct and indirect techniques, also when comparing the upper and lower arches. The only significant difference was found comparing the posterior segment of the lower arches, in which a higher percentage of detachments were recorded in group B, bonded with the indirect technique. Moreover, no significant differences between direct and indirect bonding were found when evaluating crowding level.

Aletta Hazeveld in[32] AJODO (2014) investigated the accuracy and reproducibility of physical dental models reconstructed from digital data by using 3 rapid prototyping techniques: digital light processing, jetted photopolymer, and 3-dimensional printing. All models were measured 5 times with a 2-week interval between measurements. Results displayed high intra observer agreement. The authors concluded that the dental models reconstructed by the tested rapid prototyping techniques are considered clinically acceptable in terms of accuracy and reproducibility and might be approp riate for selected applications in orthodontics.

Castilla A.E et al[16] in AO (2014) compared bracket transfer accuracy of five indirect bonding (IDB) Techniques (double polyvinyl siloxane, double vacuum-form, polyvinyl siloxane vacuum-form, polyvinyl siloxane putty, and single vacuum-form. The mesiodistal (M-D), occlusogingival (O-G), and faciolingual (F-L) positions of each bracket were measured on the working and patient models using digital photography (M-D, O-G) and calipers (F-L). Between the working and patient models, double-VF had the most teeth with significant differences and PVS-VF the fewest. When the techniques were compared, double-VF and single-VF showed significantly less accuracy in the O-G direction. He concluded that Silicon-based trays had consistently high accuracy in transferring brackets, whereas methods that exclusively used vacuum-formed trays were less consistent.

Groth, Neal D. Kravitz, Perry E.Jones Jco[30] (2014) stated that SLA printers are generally slower than the others because laser can cure only a small area at a time. FDM printers extrudes a resin that has been heated just beyond its melting point, then the heated material becomes hardens once it has been withdrawn from the liquid resin. And lastly Polyjet, The build platforms move vertically to accommodate subsequent layers it can be made as thin as 16 microns so that surface quality of PPP models is excellent.

Lincoln Issamu Nojima[59] (2015) this article assessed the precision in bracket placement and efficiency in orthodontic indirect bonding. Accuracy and reproducibility of indirect technique lead to its efficiency as an orthodontic bonding method. It provides the advantages related to indirect bonding to benefit both professionals and patients involved in this process. The indirect bonding technique should provide high accuracy in bracket placement and simple execution.

Ahmed m. El-timamy[22] (2016) introduced a new technique for evaluating the root axes in indirect bonding technique with the help of CBCT and computer aided devices were used to produce steriolithographic trays for indirect-direct bonding in a three dimensional way.3D images of brackets with different manufactures facilitate their implementation of virtual bonding. CBCT imaging together with 3D printing may help in mounting a new technique for precise bracket positioning.

Shahnaz mahamood et al[52] (2016) 3D printing is a desktop fabrication of making 3D solid objects from a digital file. Charles Hull (chuk)1984 was the first 3D systems to develop the first working 3D-printer, later in 1986 he developed an instrument called stereo lithography apparatus. Notable benefits of 3D printing are 1. Enhanced treatment procedures 2.patient treatment becomes fast, smooth and with greater precision, 3. Consistent superior appliances. Various materials are being used for 3D printing such as ABS plastic, PLA, polyamide, glass filled polyamide, silver, steel, titanium, wax, polycarbonate and stereo lithography materials .Easy,Automated model-making with 3D printer dramatically reduces fabrication times and exponentially increases output, thereby transitioning to a fully digital process, and no need of storage for bulky physical models.

Syed Abid Altaf Bukhari et al in [13](2017) compared the accuracy and time taken to perform the space analysis (arch length discrepancy and Bolton's) based on the severity of crowding using new virtual model software with that of conventional plaster models of 45 patients. He concluded, virtual models can be used as an alternative to routine plaster models in model analysis procedures, independent of severity of crowding.

S´ergio Estelita Barros et al[10] Ao (2017) evaluated the reliability and differences between the vertical compensation at the center of clinical crown and that required to level the marginal ridges. Dental casts from 200 patients were selected. Result shows The vertical discrepancy between the clinical crown centers (vdcc) and marginal ridges(vdmr) of adjacent posterior teeth were statistically significant. Clinically significant differences were observed between the maxillary second premolar and first molar and between the mandibular molars. He concluded that vpcc may not be an accurate predictor of marginal ridge leveling because the vertical compensation is necessary to level the vpcc that is not similar to level of marginal ridges.

Pitts T. R et al[15] in JCO (2017) gave the philosophy behind the protocols for bracket positioning and other biomechanics that contribute to protecting the smile arc in orthodontic patients. The upper bracket has to be positioned in such way that the smile arc has to be protected.

Cristian Zaharia et al[81] (2017) 3D printing has successfully been used since the 1980s 3D printing technology has been widely used in various fields of Dentistry for different occasions.3D printed restorations surely are on top of all. Although some disadvantages are there like cost, available only in specific materials, also resin causes skin irritation, inflammation by contact and inhalation. By further research can make the 3D printing technology can be used as widely, although this can act as a substitute for the conventional work flow.

Jiyeon kim[42] (2018) evaluated the effect of cusp height of posterior teeth (first premolar, second premolar, first molar) on the accuracy of the computer-aided design and computer-aided manufacturing (cad/cam) indirect bonding system. Five maxillary arch models were taken without any attrition divided in to 2 groups. Control group with 0.5mm grinding and 0.5mm of wax add up in cusp tips. Rapid proto type models were printed for both groups and transfer jigs were designed using digital model. 3-dimensional program is used to evaluate the differences between the intended digital bracket position and actual bracket position after indirect bonding.This study concluded that a difference in cusp height of maxillary posterior teeth did not produce a statistically significant difference in the linear and angular dimensions of bracket placement with the cad/cam indirect bonding system.

Rebong R. E et al[64] in AO (2018) evaluated the dimensional accuracy of Polyjet, and stereolithographic (SLA) and fused deposition modeling (FDM), – produced models, by comparing them to traditional plaster casts. Plaster models were scanned, saved as stereolithiography files, and printed as physical models using three different three-dimensional (3D) printers.A digital caliper was used to obtain measurements on the original plaster models as well as on the printed resin models. He concluded that the Dental models reconstructed by FDM technology had the fewest dimensional measurement differences compared to plaster models.

Oliveira N. S and Pretti H[18] in IJOH (2018) evaluated the quality of individual positions of the attachments will make it possible to foresee positions that may lead to undesired orthodontic movements. The authors listed imprecision factors associated with traditional bonding methods, as well as present evidence about the software systems that incorporate digital technology to vestibular bonding. Although digital systems did not demonstrate to guarantee accuracy, virtual orthodontics is now an irrevocable for enabling more efficacy and therapeutic control.

Kalra R.K et al in JCDR[39] (2018) compared the accuracy of bracket placement by Direct and Indirect Bonding techniques using digitally captured and processed images. Ideal bracket positioning of twelve sets were compared using Digital processing. He concluded that neither technique yielded ideal bracket placement, however, Indirect bonding was better in terms of accuracy more often (70% for vertical & 60% for horizontal positioning).

Christian Groth et al[29] in Jco (2018), he stated that biggest advantage of digital printing is their precision and durability. Using CAD/ CAM software the models can be repaired or altered accurately prior to printing it has numerous advantages like shorter appointments and patient comfort, avoidance of impression redundancy ,elimination of shipping expenses, model breakage, better communication with lab technician. Main disadvantage is cost and maintenance of 3D printer. Then the printed models will be made from the orthodontic laboratory. As in future 3D printing technology improves the orthodontist to prescribe, design and manufacture orthodontic products in offices itself.

Materials and Methods

MATERIALS AND METHODS

The **present in-vivo study** included 10 patients between the age of 15-30 years from the department of orthodontics who required fixed appliance therapy. All types of malocclusions including extraction and non-extraction cases were included. Following criterias were followed for sample selection,

Inclusion criteria

- Patients with crowded dentition
- Proclined dentition
- Non carious teeth
- Permanent dentition

Exclusion criteria

- Patients having systemic disease
- Fractured teeth
- Demineralised enamel
- Teeth with caries
- Fluorosis, amelogenisis imperfect.

This study is a full mouth study .Out of 10 samples patients were randomly divided in to 2 groups, group A (study group) and group B (control group).Indirect bonding in group A and conventional direct bonding in group B. we have used 3M Gemini MBT .022in bracket kit, mimics software (version20),cone beam computed tomography, biocompatible transparent 3D printing resin ,models, canon 700D camera. Experienced orthodontists are selected to place brackets in both groups. .

INDIRECT BONDING METHOD (GROUP A)

- Each brackets in the bracket kit (3M Gemini MBT .022 in) is scanned using structured light scanner .The images will be first obtained in DICOM format and then converted to stereolithographic format.
- **CBCT** took for the patient. Each tooth extracted from the CBCT including the root of the tooth.
- Patient's cast digitally scanned and superimposed on the CBCT images.
- On the tooth we took 5 reference planes for bracket positioning, incisal or occlusal, mesial, distal, long axis (vertical), mesiodistal (horizontal).Then positioned the scanned bracket on each tooth according to the MBT bracket height chart and positioned accurately using the **mimics software**(version20) tools (Geomagic freeform plus software).
- After the bracket being placed, a 3D image of U shaped stent will be added to the project.
- Then the image of the stent will be placed over the teeth half of the brackets covered, leaving the other half of the brackets uncovered. In

the mimics software the teeth and the bracket will be then subtracted from the image of the tray to have a negative replica.

- The subtracted image of the tray in steriolithographic format will be printed with a **3D printer** (SLA printing technique, machine-formlabs form2 for rigid splint and polyjet printing technique,machine-stratsays J750 for soft splint) to obtain a 3D printed bracket positioning tray with indentation for bracket seating.
- The actual brackets will be then transferred to the printed trays and the whole assembly will be ready for direct bonding in patient's mouth.
- Enamel surfaces of the teeth to be bonded indirectly were prepared in a similar manner to those that received direct bonding.
- Printed tray with seated bracket was then placed on their perspective arches and light cured **(Transbond-XT**) for 40 seconds on mesial, distal, occlusal and gingival surface over the transfer tray.
- Then the trays were removed away gently from the teeth to complete the procedure.

DIRECT BONDING TECHNIQUE (GROUP B)

- Patients selected for direct bonding was subjected to pumice prophylaxis with a prophy cup.
- All the teeth to be bonded were then etched for 30 seconds with 37% orthophosphoric acid and rinsed thoroughly; the teeth were dried with oil free source.

- The teeth were then coated with the primer and cured for 20 seconds each.
- Light cured resin was applied on the bracket bases and then manually positioned.
- Position of the bracket mesio distally was determined visually and height was checked with a **MBT** bracket positioning gauge.
- **Transbond-XT** was used to bond the bracket to tooth surface.
- The bracket was cured for 10seconds on the buccal, 10seconds on the gingival surface, 10seconds on mesial, 10 seconds on the distal surfaces.

ASSESSMENT

- To evaluate the bracket positioning **models** and **photographs** of each tooth were taken for both groups and compared the errors.
- All photographs were taken on a canon digital camera equipped with 100mm macro lens with 1:1 magnification and ring flash .a jig was constructed with a rectangular wire (19*25inch) set a distance of 150mm for standardization.
- By using the imageJ application all following measurements are taken.

  Linear measurements

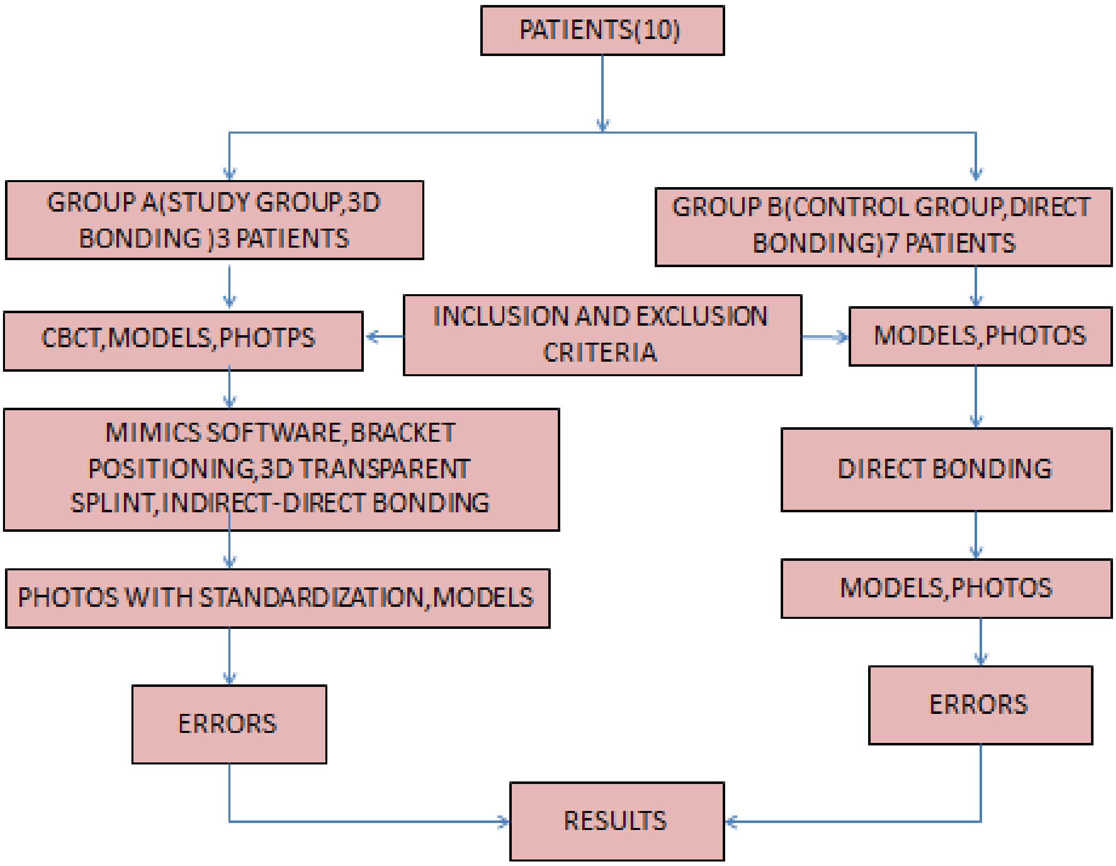
  - Vertical height measurements from incisal or cuspal tip
  - Horizontal measurements (mesial and distal)
  - Total clinical crown height.

- Marginal ridges to the center of bracket
- Marginal ridges to the cusp height

Angular measurements

- Angle formed between long axis of the teeth and long axis of the bracket (axial inclination).
- Angle formed between incisal plane and bracket base(paralleling error).
- Angle formed between bracket base and incisal edge (thickening error).

By using CBCT we measured the approximation of root position and the bracket position.The measurements taken from the teeth bonded with the 2 techniques were compared statistically to each other. Comparison between the groups is done using Mann whitney U-test (software: spss ibm version 22).

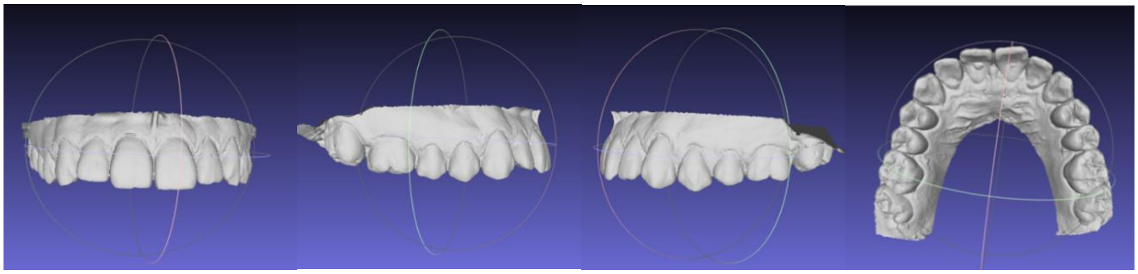

PATIENTS(10)
GROUP A(STUDY GROUP,3D BONDING)3 PATIENTS
GROUP B(CONTROL GROUP,DIRECT BONDING)7 PATIENTS
CBCT,MODELS,PHOTPS
INCLUSION AND EXCLUSION CRITERIA
MODELS,PHOTOS
MIMICS SOFTWARE,BRACKET POSITIONING,3D TRANSPARENT SPLINT,INDIRECT-DIRECT BONDING
DIRECT BONDING
PHOTOS WITH STANDARDIZATION,MODELS
MODELS,PHOTOS
ERRORS
ERRORS
RESULTS

(Flow chart .1)

Figures

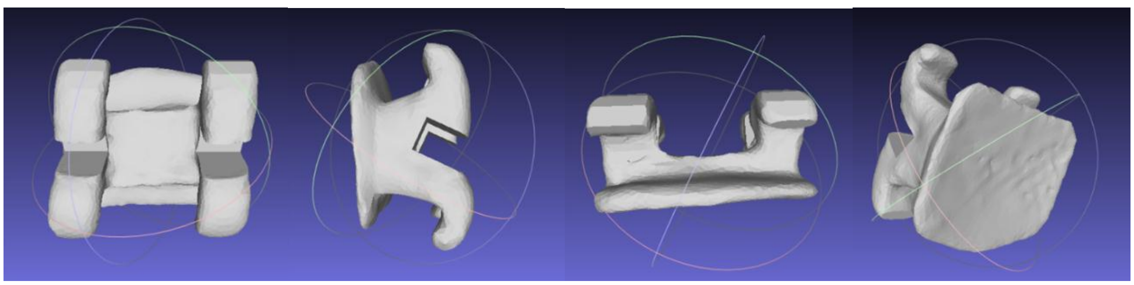
STUDY GROUP (GROUP A)

Step1



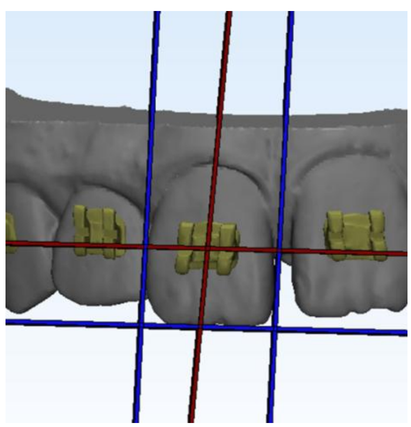
Digitally scanned steriolithographic file image of the cast

Step 2

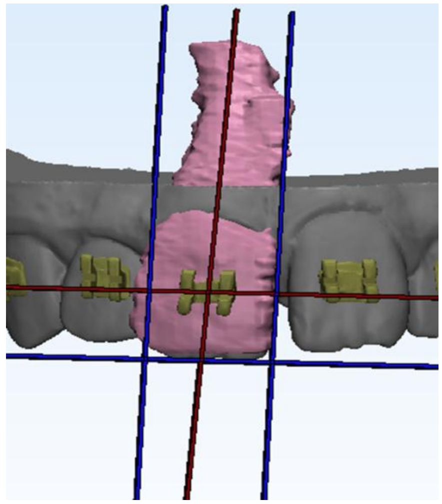


Scanned steriolithographic file image of the 3M Gemini MBT bracket
(structured light scanning)

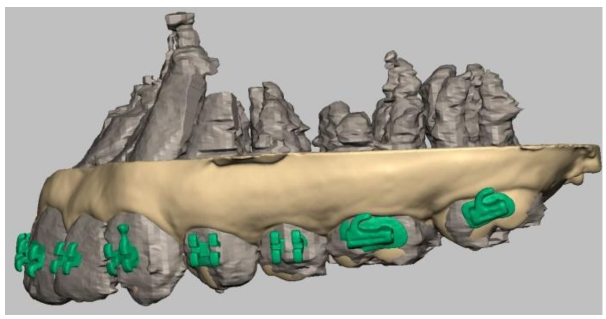
Step 3



Mesial,distal,incisal,central reference plane given and bracket positioned using mimics software tools

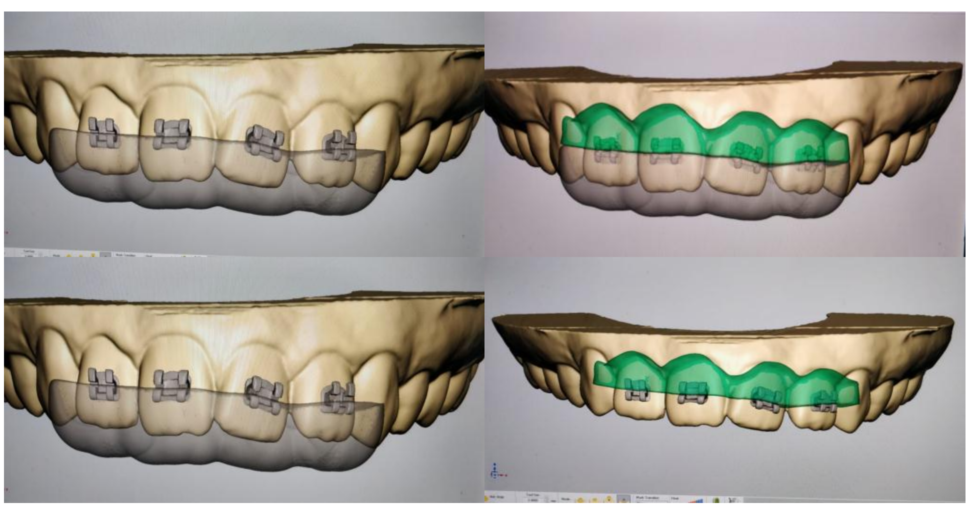


Root extracted from CBCT Superimposed on the digital model to check the root angulation



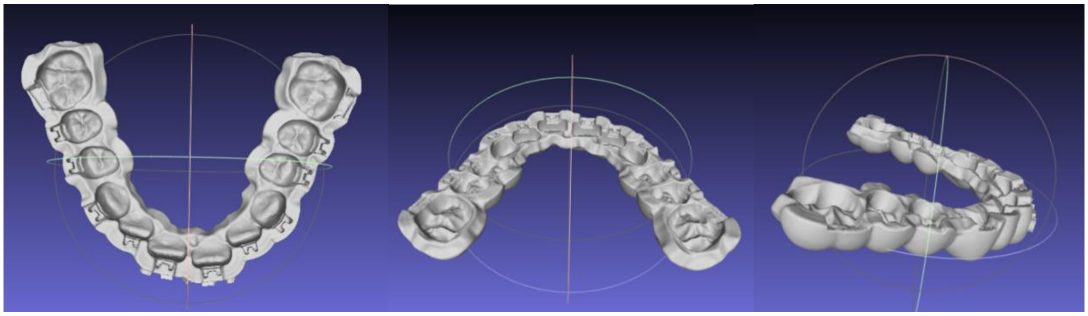
3D bracket positioning in mimics software (version20) using Geomagic freeform plus software

Step 4



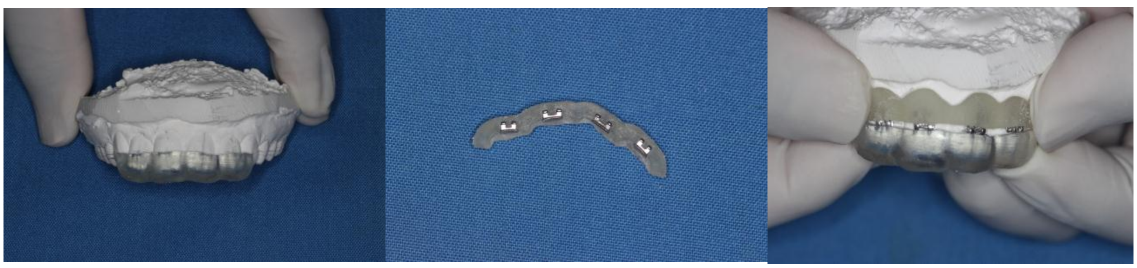
The image of the 3D stent placed over the teeth and half of the brackets, leaving the other half of the brackets uncovered

Step 5



Three dimensional splint design

Step 6



a) b) c)

a) 3D printed transparent splint with cast (Incisal portion)

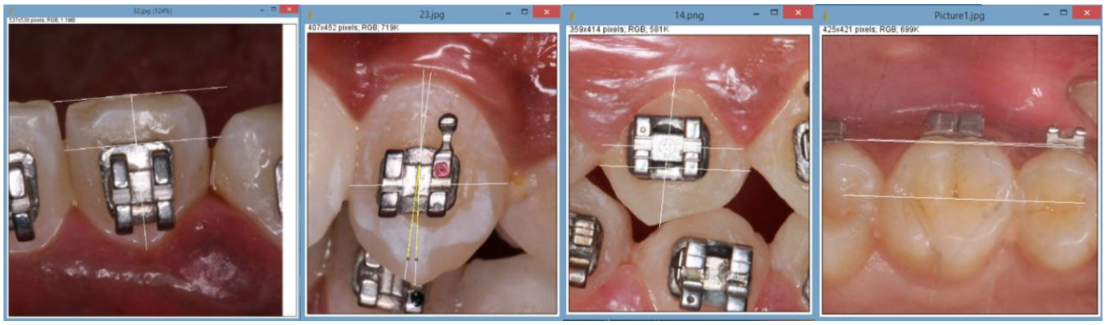
b) Transfer tray made up of soft flexible material, Tango+vero clear (gingival portion)

c) Bracket transferred for direct bonding

Step 7

Splint checked in patient’s mouth, bracket positioned and bonding done.

Step 8



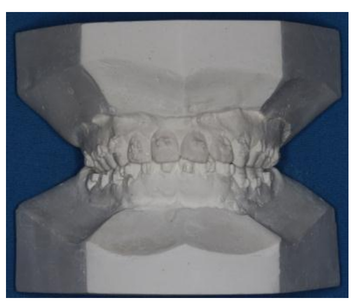
Vertical measurements, paralleling error, long axis, mesio distal measurements, marginal ridge to FACC, marginal ridge to centre of brackets and thickening error, has done in ImageJ application with the help of the plaster model.

CONTROL GROUP (GROUP B)

Step1

After bonding photos taken with canon digital camera equipped with 100mm lens and ring flash

Step2



Impression took with alginate, and cast poured

Step3

Same measurement technique followed in both groups (step8 in study group)

Results

RESULTS

280 brackets were evaluated for accuracy of placement, including buccal tubes (84-study group, 196-control group). A photographic technique as well as models were used to measure the accuracy of bracket positioning. All study samples are accomplished with the inclusion criteria.

The statistical analysis - non parametric - used in the study. Comparison between the groups is done using Mann Whitney U-test (Software: spss ibm version 22). P value interpretation: P value < 0.05 is statistically significant, P value >0.05 is not statistically significant.

FORM OF COMPARISON

- Relative accuracy bracket positioning between 2 techniques on all teeth.
- Descriptive statistics for three variables including total clinical crown height, marginal ridge to center of bracket and marginal ridge to the FACC.

FINDINGS

When comparing the all 5 variables, it showing that there is a statistically significant (< 0.05) difference between the indirect and direct bonding group, in which indirect bonding group showing superior to direct bonding precision.

LINEAR MEASUREMENT

1. Vertical bracket placement in relation to 25(mean error in group A=0.256 and group B=0.878), 36 (mean error in group A=0.077and group B=.385), 37(mean error in group A=0.395 and group B=1.025), 41(mean error in group A=0.004and group B=0.655) and 43(mean error in group A=0.239 and group B=0.531) showed greater precision in bracket placement with indirect bonding. (Table 1,2 & 3)
2. Horizontal error - In indirect bonding 31(mean error in group A=0.027 and group B=0.023), 33(mean error in group A=0.126 and group B=0.710), and 42(mean error in group A=0.133 and group B=0.514) showed improved bracket positioning in the mesial side. (Table 4,5 & 6) In the distal side 31(mean error in group A=0.023 and group B=0.283), 33(mean error in group A=0.144 and group B=0.710) and 42(mean error in group A=0.033 and group B=0.303) showed statistically significant difference. (Table 7,8 & 9)

ANGULAR MEASUREMENTS

1. Long axis error (long axis of the tooth with the long axis of the bracket) in relation to 16(mean error in group A=0.000 and group B=1.425), 33(mean error in group A=0.284 and group B=2.771) and 45(mean error in group A=0.000 and group B=3.335) yielded better results with indirect bonding technique. (Table 10,11 & 12)

3. Paralleling error (incisal plane with bracket base) results of 11(mean error in group A=0.082 and group B=2.957), 14(mean error in group A=0.269 and group B=1.609) and 16 (mean error in group A=.000 and group B=2.406) showed better bracket position in the indirect group. (Table 13,14 & 15)
4. Thickening error- This variable alone showed no statistical difference between both the groups. There is no previous study carried out with assessing thickening error. (Table 16,17 & 18)

In all 5 variables vertical measurements showed better precision with indirect bonding. Technique and thickening error showed no significant difference between the errors in both groups. Mean total error in the indirect bonding technique is (0.463) less when compared with the direct bonding technique (0.557).Mean total crown height, distance from the marginal ridge to center of bracket and distance from the marginal ridge to FACC in both groups have explained in graph separately (Figure 1,figure 2 and figure 3).

Tables and Graphs

TABLE 1: MEAN ERRORS OF VERTICAL BRACKET HEIGHT MEASUREMENT

GROUP A (Indirect Bonding)

	N	Minimum	Maximum	Mean	Std. Deviation
11	3	.112	.512	.27467	.210194
12	3	.450	.900	.75000	.259808
13	3	.080	.750	.52667	.386825
14	3	.000	.750	.37000	.375100
15	3	.290	.300	.29633	.005508
16	3	.050	.050	.05000	.000000
17	3	.148	.650	.42400	.254708
21	3	.180	.500	.39333	.184752
22	3	.250	.790	.61000	.311769
23	3	.070	.730	.51000	.381051
24	3	.200	.760	.57333	.323316
25	3	.170	.300	.25667	.075056
26	3	.060	.077	.07133	.009815
27	3	.311	.672	.48767	.180622
31	3	.000	.750	.25000	.433013
32	3	.302	.770	.45800	.270200
33	3	.257	1.200	.57133	.544441
34	3	.109	.700	.36967	.212154
35	3	.807	1.498	1.26767	.398949
36	3	.001	.230	.07733	.032213
37	3	.211	.490	.39533	.159657
41	3	.0010	.0100	.004000	.0051962
42	3	.279	.290	.28267	.006351
43	3	.195	.261	.23900	.038105
44	3	.790	1.701	1.39733	.525966
45	3	.809	1.502	1.27100	.400104
46	3	.698	1.207	.96767	.255852
47	3	.269	.580	.45333	.163323

TABLE 2: MEAN ERRORS OF VERTICAL BRACKET HEIGHT MEASUREMENTS

GROUP B (Direct bonding)

	N	Minimum	Maximum	Mean	Std. Deviation
11	7	.024	1.693	.81243	.610634
12	7	.078	1.393	.83057	.571996
13	7	.102	1.836	1.05000	.692390
14	7	.180	1.555	.71686	.535547
15	7	.050	1.668	.71643	.547687
16	7	.033	1.011	.59000	.333063
17	7	.021	1.214	.74129	.412187
21	7	.234	1.794	.91729	.615095
22	7	.230	1.436	.71529	.442263
23	7	.128	1.482	.90843	.485698
24	7	.470	2.054	.98200	.580258
25	7	.316	1.975	.87857	.588324
26	7	.134	1.021	.59643	.287697
27	4	0	1	.51	.370
31	7	.119	1.173	.47614	.372664
32	7	.365	.766	.53214	.158009
33	7	.321	.998	.69857	.261561
34	7	.202	.873	.49571	.236301
35	7	.180	1.179	.49743	.456652
36	7	.030	.620	.38586	.244588
37	7	.514	1.931	1.02557	.504081
41	7	.2300	1.1680	.655714	.4137651
42	7	.122	2.397	.73300	.794159
43	7	.286	.771	.53171	.188506
44	7	.140	1.865	.81343	.582739
45	7	.190	1.430	.82429	.413498
46	7	.502	1.091	.77714	.262679
47	7	.489	1.477	.86457	.412140

TABLE 3: COMPARISON OF MEAN ERROR IN VERTICAL BRACKET POSITIONING MEASUREMENTS

TOOTH NO.	P VALUE (0.05)	TOOTH NO.	P VALUE (0.05)
11	.210	31	.304
12	.646	32	.422
13	.304	33	.422
14	.425	34	.051
15	.304	35	.052
16	.084	36	.016
17	.210	37	.017
21	.137	41	.016
22	.732	42	.732
23	.137	43	.016
24	.304	44	.304
25	.016	45	.137
26	.304	46	.305
27	.559	47	.138

TABLE 4: MEAN ERRORS OF MESIAL BRACKET POSITIONING MEASUREMENTS

GROUP A (Indirect Bonding)

	N	Minimum	Maximum	Mean	Std. Deviation
11	3	.0090	.4390	.167000	.2365840
12	3	.0010	.4800	.267667	.2440785
13	3	.020	.870	.38100	.439219
14	3	.388	.910	.65133	.261031
15	3	.216	.730	.39333	.291701
16	3	.180	.390	.27667	.105987
17	3	.220	.670	.40900	.233480
21	3	.010	.109	.04467	.055770
22	3	.000	.300	.10667	.167730
23	3	.091	.356	.20867	.134968
24	3	.352	1.000	.61133	.342814
25	3	.090	1.310	.67333	.611746
26	3	.0020	.8360	.325333	.4474476
27	3	.136	.298	.23200	.085065
31	3	.0071	.0543	.02702	.01561570
32	3	.017	.566	.20167	.315532
33	3	.010	.295	.12600	.110204
34	3	.259	.800	.53667	.270785
35	3	.135	.926	.54033	.395867
36	3	.125	.610	.37100	.242576
37	3	.194	.499	.30533	.168346
41	3	.0020	.0620	.022333	.0343560
42	3	.000	.252	.13333	.128937
43	3	.043	.957	.36167	.516001
44	3	.141	.293	.22467	.077151
45	3	.157	.381	.28800	.116735
46	3	.115	1.060	.55667	.475508
47	3	.004	1.510	.58800	.807894

TABLE 5: MEAN ERRORS OF MESIAL BRACKET POSITIONING MEASUREMENTS

GROUP B (Direct Bonding)

	N	Minimum	Maximum	Mean	Std. Deviation
11	7	.0360	.6470	.247000	.2148969
12	7	.0160	.3850	.186143	.1584565
13	7	.040	.646	.34600	.235267
14	7	.083	1.275	.41757	.501583
15	7	.010	.885	.39986	.311611
16	7	.010	2.119	.59957	.760884
17	7	.010	1.435	.73714	.485239
21	7	.023	.729	.22114	.255105
22	7	.000	.593	.18200	.202486
23	7	.105	1.550	.59714	.527190
24	7	.000	1.303	.40286	.446863
25	7	.165	1.854	.55243	.594848
26	7	.0360	1.4840	.742000	.5367911
27	7	.087	1.459	.80314	.464361
31	7	.001	.050	.02367	.24705
32	7	.013	.898	.38514	.408048
33	7	.602	.774	.71033	.090290
34	7	.028	1.119	.41757	.486037
35	7	.054	.765	.38986	.272703
36	7	.330	.901	.59200	.228994
37	7	.215	.998	.56400	.236210
41	7	.0650	1.1180	.435000	.3327141
42	7	.060	2.025	.51400	0.813673
43	7	.165	2.607	.55429	.906145
44	7	.080	1.242	.37714	.398320
45	7	.050	1.515	.63814	.550240
46	7	.097	1.112	.59029	.367851
47	7	.207	1.084	.52971	.339108

TABLE 6: COMPARISON OF MEAN ERRORS MESIAL BRACKET POSITIONING BETWEEN BOTH GROUPS

TOOTH NO.	P VALUE (0.05)	TOOTH NO.	P VALUE (0.05)
11	.425	31	.016
12	.732	32	.304
13	.909	33	.016
14	.304	34	.304
15	.909	35	.732
16	.819	36	.304
17	.210	37	.087
21	.138	41	.016
22	.493	42	.016
23	.210	43	.304
24	.305	44	.732
25	.732	45	.732
26	.304	46	.909
27	.087	47	.909

TABLE 7: MEAN ERROR OF THE DISTAL BRACKET POSITIONING MEASUREMENTS

GROUP A (Indirect Bonding**)**

	N	Minimum	Maximum	Mean	Std. Deviation
11	3	.0090	.4390	.167000	.2365840
12	3	.000	.480	.26667	.244404
13	3	.020	.870	.38000	.439659
14	3	.390	.912	.65400	.261052
15	3	.220	.725	.39167	.288718
16	3	.180	.390	.27533	.106327
17	3	.2200	.6660	.407667	.2312452
21	3	.0060	.1100	.045333	.0564388
22	3	.002	.300	.10700	.167359
23	3	.090	.360	.21000	.137477
24	3	.350	1.000	.61000	.343948
25	3	.090	1.310	.67433	.611618
26	3	.002	.836	.32533	.447448
27	3	.136	.300	.23267	.085845
31	3	.000	.050	.02333	.025166
32	3	.002	.566	.19500	.321383
33	3	.012	.295	.14471	.109805
34	3	.260	.800	.53667	.270247
35	3	.140	.930	.54333	.395264
36	3	.130	.610	.37333	.240069
37	3	.194	.499	.30533	.168346
41	3	.0020	.0620	.022333	.0343560
42	3	.0000	.0520	.033333	.0289367
43	3	.043	.957	.36167	.516001
44	3	.140	.290	.22333	.076376
45	3	.160	.380	.29000	.115326
46	3	.1150	1.0600	.556667	.4755085
47	3	.004	1.510	.58800	.807894

TABLE 8: MEAN ERRORS OF THE DISTAL BRACKET POSITIONING MEASUREMENTS

GROUP B (direct Bonding)

	N	Minimum	Maximum	Mean	Std. Deviation
11	7	.0360	.9850	.367714	.3436911
12	7	.000	.385	.15786	.172615
13	7	.000	.660	.33500	.255469
14	7	.080	2.546	.75500	.929938
15	7	.000	.885	.38286	.327997
16	7	.014	2.119	.73900	.731025
17	7	.0110	2.3500	.867996	.7534067
21	7	.0000	.7290	.209143	.2643435
22	7	.030	1.229	.35771	.426473
23	7	.105	3.564	1.08029	1.197864
24	7	.000	1.303	.40200	.447397
25	7	.170	2.568	.87271	.950057
26	7	.000	1.484	.73314	.545868
27	7	.090	5.230	1.48800	1.706398
31	7	.000	.850	.02833	.025166
32	7	.013	.898	.33429	.352018
33	7	.610	.770	.71000	.087178
34	7	.028	1.119	.35914	.406448
35	7	.050	.960	.49857	.329979
36	7	.169	1.406	.64829	.407815
37	7	.215	.998	.51857	.271159
41	7	.0000	1.1190	.366857	.3697817
42	7	.0600	.7760	.303600	.2680056
43	7	.165	2.607	.59257	.892515
44	7	.083	1.242	.38214	.395805
45	7	.052	2.515	.59000	.551425
46	7	.0060	1.1120	.530429	.4283452
47	7	.009	1.084	.50143	.376688

TABLE 9: COMPARISON OF MEAN ERRORS DISTAL BRACKET POSITIONING IN BOTH GROUPS

TOOTH NO.	P VALUE (0.05)	TOOTH NO.	P VALUE (0.05)
11	.305	31	.017
12	.648	32	.305
13	.909	33	.017
14	.732	34	.210
15	.909	35	.909
16	.425	36	.305
17	.210	37	.209
21	.305	41	.087
22	.210	42	.016
23	.087	43	.305
24	.305	44	.648
25	.909	45	.210
26	.425	46	.732
27	.087	47	.909

TABLE 10: MEAN ERRORS OF THE LONG AXIS OF THE BRACKET POSITIONING

GROUP A (Indirect Bonding)

	N	Minimum	Maximum	Mean	Std. Deviation
11	3	.000	.000	.00000	.000000
12	3	.000	.000	.00000	.000000
13	3	.000	.854	.49300	.442037
14	3	.000	1.245	.41500	.718801
15	3	.000	.000	.00000	.000000
16	3	.000	.000	.00000	.000000
17	3	.000	.130	.04500	.073020
21	3	.000	.000	.00000	.000000
22	3	.000	.485	.16167	.280015
23	3	.000	.123	.04100	.071014
24	3	.000	.000	.00000	.000000
25	3	.000	.000	.00000	.000000
26	3	.000	.312	.10400	.180133
27	3	.000	.000	.00000	.000000
31	3	.000	.247	.08233	.142606
32	3	.000	.214	.07133	.123553
33	3	.000	.852	.28400	.491902
34	3	.000	.256	.08533	.147802
35	3	.000	.000	.00000	.000000
36	3	.000	.410	.13667	.236714
37	3	.000	.140	.04152	.127120
41	3	.000	.124	.08167	.070741
42	3	.000	.241	.08033	.139141
43	3	.000	.000	.00000	.000000
44	3	.000	.359	.19667	.181946
45	3	.000	.000	.00000	.000000
46	3	.000	.358	.11933	.206691
47	3	.000	.214	.05124	.123400

TABLE 11: MEAN ERRORS LONG AXIS OF THE BRACKET POSITIONING

GROUP B (Direct bonding)

	N	Minimum	Maximum	Mean	Std. Deviation
11	7	.000	8.186	1.68514	3.027471
12	7	.000	9.100	2.14414	3.404498
13	7	.000	8.421	4.11171	3.212263
14	7	.000	9.110	3.01486	3.634151
15	7	.000	8.609	2.44271	4.171870
16	7	.000	3.432	1.42586	1.283388
17	7	.000	2.749	1.08743	0.983710
21	7	.000	7.850	1.82471	3.228812
22	7	.000	1.265	.49600	.625172
23	7	.000	10.623	3.62271	4.724952
24	7	.000	9.300	2.87743	3.209102
25	7	.000	7.680	2.63271	3.120242
26	7	.000	2.356	.33657	.890484
27	7	.000	3.719	.48120	.942810
31	7	.000	5.126	1.44086	2.187840
32	7	.000	.000	.00000	.000000
33	7	.000	4.980	2.77100	1.925563
34	7	.000	13.251	3.18814	5.082881
35	7	.000	6.780	2.12271	2.540789
36	7	.000	5.243	1.40186	2.139597
37	7	.000	3.240	0.97132	1.81036
41	7	.000	1.203	.30771	.530533
42	7	.000	6.040	.99143	2.251336
43	7	.000	5.511	2.09643	1.854217
44	7	.000	4.600	1.21886	1.961097
45	7	.000	5.888	3.33514	2.019717
46	7	.000	3.029	1.00957	1.134807
47	7	.000	2.410	0.09816	0.159870

TABLE 12: COMPARISON OF MEAN ERRORS IN THE LONG AXIS OF BRACKET POSITIONING IN BOTH GROUPS

TOOTH NO.	P VALUE (0.05)	TOOTH NO.	P VALUE (0.05)
11	.207	31	.521
12	.207	32	.127
13	.204	33	.049
14	.274	34	.521
15	.329	35	.123
16	.048	36	.521
17	.062	37	.061
21	.329	41	.608
22	.521	42	.888
23	.274	43	.068
24	.068	44	.903
25	.123	45	.034
26	.626	46	.274
27	.095	47	.081

TABLE 13: MEAN ERRORS OF THE PARALLELING ERROR IN THE BRACKET POSITIONING

GROUP A (Indirect Bonding)

	N	Minimum	Maximum	Mean	Std. Deviation
11	3	.000	.247	.08233	.142606
12	3	.000	.000	.00000	.000000
13	3	.000	.235	.07833	.135677
14	3	.000	.809	.26967	.467076
15	3	.000	.000	.00000	.000000
16	3	.000	.000	.00000	.000000
17	3	.000	1.238	.41267	.714760
21	3	.0	.0	.000	.0000
22	3	.000	.874	.29133	.504604
23	3	.000	.199	.06633	.114893
24	3	.000	.000	.00000	.000000
25	3	.000	1.585	.52833	.915100
26	3	.000	.104	.03467	.060044
27	3	.000	.210	.07000	.121244
31	3	.000	.105	.03500	.060622
32	3	.000	.000	.00000	.000000
33	3	.000	.211	.07033	.121821
34	3	.000	.000	.00000	.000000
35	3	.000	.145	.04833	.083716
36	3	.000	.000	.00000	.000000
37	3	.0000	1.0030	.334333	.5790823
41	3	.000	.659	.40600	.355144
42	3	.000	.263	.08767	.151843
43	3	.000	.120	.04000	.069282
44	3	.000	.000	.00000	.000000
45	3	.000	.000	.00000	.000000
46	3	.0	.0	.000	.0000
47	3	.000	.189	.06300	.109119

TABLE 14: MEAN ERROR OF THE PARALLELING ERROR IN THE BRACKET POSITIONING

GROUP B (Direct bonding)

	N	Minimum	Maximum	Mean	Std. Deviation
11	7	.000	6.090	2.95757	2.066560
12	7	.000	2.501	1.14271	.886777
13	7	.000	1.000	.14286	.377964
14	7	.980	2.589	1.60929	.660122
15	7	.000	2.351	.33586	.888594
16	7	1.000	3.560	2.40614	.843861
17	7	.000	4.230	1.13871	1.506934
21	7	.0	.0	.000	.0000
22	7	.000	.000	.00000	.000000
23	7	.000	1.870	.26714	.706794
24	7	.000	3.623	1.56771	1.353778
25	7	.874	3.740	2.36000	1.038193
26	7	.000	1.235	.48900	.614927
27	7	.000	3.120	.75857	1.163885
31	7	.000	3.027	1.00257	1.185944
32	7	.000	2.542	.54743	1.002340
33	6	.000	1.901	.31683	.776080
34	7	.000	.897	.25286	.354118
35	6	.000	1.342	.26267	.536984
36	7	.000	3.251	1.10471	1.530059
37	7	.0000	2.3100	1.257570	.9670890
41	7	.000	1.235	.43214	.578405
42	6	.000	6.040	1.01717	2.460805
43	7	.000	1.325	.20086	.496619
44	7	.000	2.541	.70086	1.198019
45	7	.000	2.310	.68271	.923886
46	7	.0	.0	.000	.0000
47	7	.000	2.156	.59614	1.018896

TABLE 15: COMPARISON OF MEAN ERRORS IN THE PARALLELING ERROR OF BRACKET POSITIONING IN BOTH GROUPS

TOOTH NO.	P VALUE (0.05)	TOOTH NO.	P VALUE (0.05)
11	.049	31	.274
12	.068	32	.329
13	.626	33	.724
14	.016	34	.207
15	.513	35	.759
16	.015	36	.207
17	.543	37	.196
21	1.000	41	.903
22	.127	42	1.000
23	.626	43	.888
24	.068	44	.329
25	.054	45	.207
26	.521	46	1.000
27	.521	47	.888

TABLE 16: MEAN THICKENING ERRORS IN THE BRACKET POSITIONING

GROUP A (Indirect Bonding)

	N	Minimum	Maximum	Mean	Std. Deviation
11	3	.000	.000	.00000	.000000
12	3	.0	.0	.000	.0000
13	3	.000	.214	.07133	.123553
14	3	.000	1.001	.66733	.577928
15	3	.000	.000	.00000	.000000
16	3	.0	.0	.000	.0000
17	3	.000	.000	.00000	.000000
21	3	.0	.0	.000	.0000
22	3	.0	.0	.000	.0000
23	3	.000	.156	.05200	.090067
24	3	.000	1.020	.34000	.588897
25	3	.0	.0	.000	.0000
26	3	.0	.0	.000	.0000
27	3	.000	.000	.00000	.000000
31	3	.000	.000	.00000	.000000
32	3	.000	.000	.00000	.000000
33	3	.000	.351	.19633	.179171
34	3	.000	.000	.00000	.000000
35	3	.000	.455	.15167	.262694
36	3	.000	.000	.00000	.000000
37	3	.000	.000	.00000	.000000
41	3	.000	.000	.00000	.000000
42	3	.000	.000	.00000	.000000
43	3	.000	.000	.00000	.000000
44	3	.000	.562	.18733	.324471
45	3	.000	1.101	.51867	.553254
46	3	.000	.000	.00000	.000000
47	3	.000	.000	.00000	.000000

TABLE 17: MEAN THICKENING ERRORS IN THE BRACKET POSITIONING

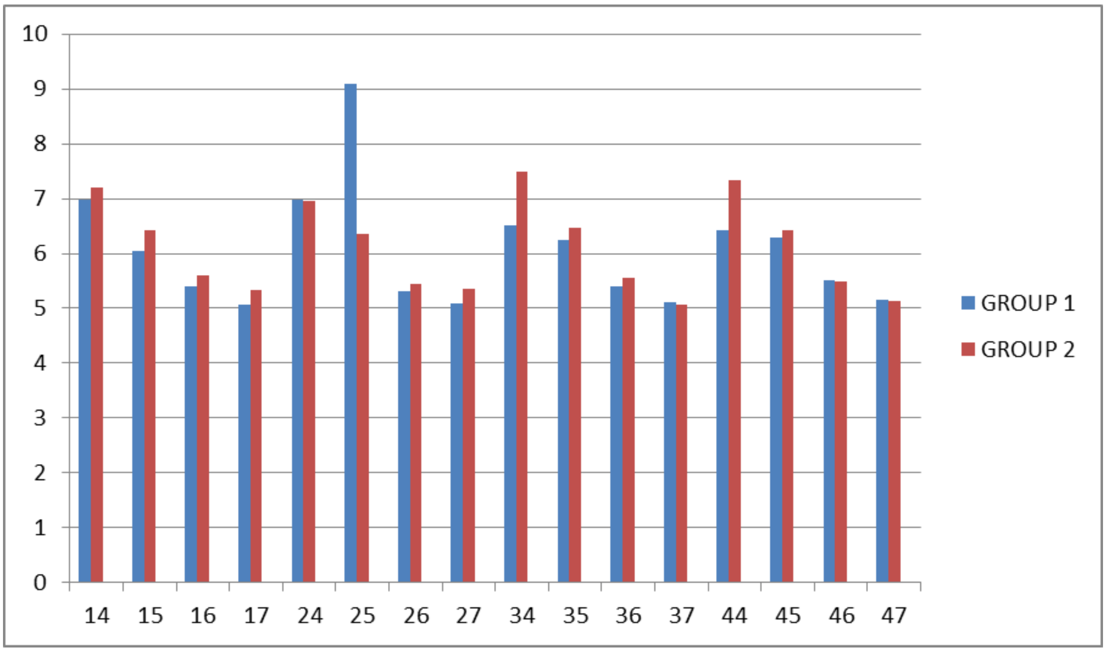
GROUP B (Direct Bonding)

	N	Minimum	Maximum	Mean	Std. Deviation
11	7	.000	1.091	.15586	.412359
12	7	.0	.0	.000	.0000
13	7	.000	1.259	.71600	.669787
14	7	.000	1.200	.17143	.453557
15	7	.000	1.739	.28143	.648468
16	7	.0	.0	.000	.0000
17	7	.000	1.039	.14843	.392705
21	7	.0	.0	.000	.0000
22	7	.0	.0	.000	.0000
23	7	.000	3.391	.95043	1.208000
24	7	.000	.985	.14071	.372295
25	7	.0	.0	.000	.0000
26	7	.0	.0	.000	.0000
27	7	.000	.253	.03614	.095625
31	7	.000	.000	.00000	.000000
32	7	.000	1.580	.37686	.661011
33	7	.000	2.001	1.11400	.844981
34	7	.000	1.051	.15014	.397241
35	7	.000	.000	.00000	.000000
36	7	.000	.985	.14071	.372295
37	7	.000	.987	.24071	.419478
41	7	.000	.000	.00000	.000000
42	7	.000	.000	.00000	.000000
43	7	.000	2.968	.60814	1.084059
44	7	.000	2.987	.71500	1.252725
45	7	.000	1.235	.17643	.466786
46	7	.000	.234	.03343	.088444
47	7	.000	.000	.00000	.000000

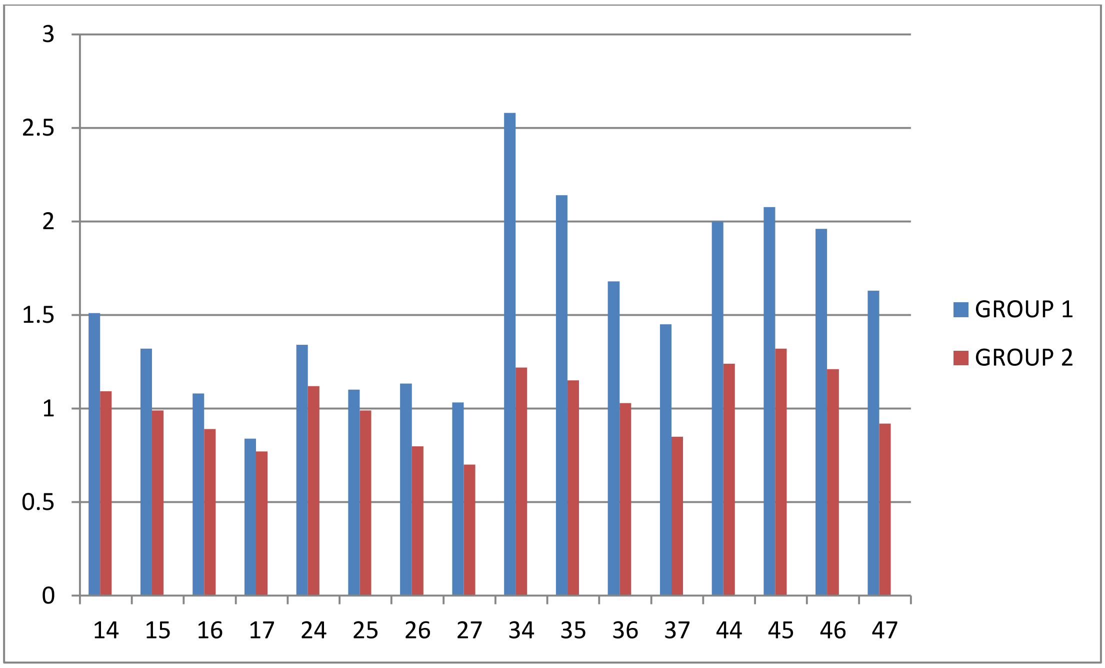
TABLE 18: COMPARISON OF MEAN THICKENING ERRORS OF THE BRACKET POSITIONING IN BOTH GROUPS

TOOTH NO.	P VALUE (0.05)	TOOTH NO.	P VALUE (0.05)
11	.513	31	1.000
12	1.000	32	.329
13	.272	33	.204
14	.205	34	.513
15	.329	35	.127
16	1.000	36	.513
17	.513	37	.329
21	1.000	41	1.000
22	1.000	42	1.000
23	.274	43	.207
24	.416	44	.888
25	1.000	45	.207
26	1.000	46	.513
27	.513	47	1.000

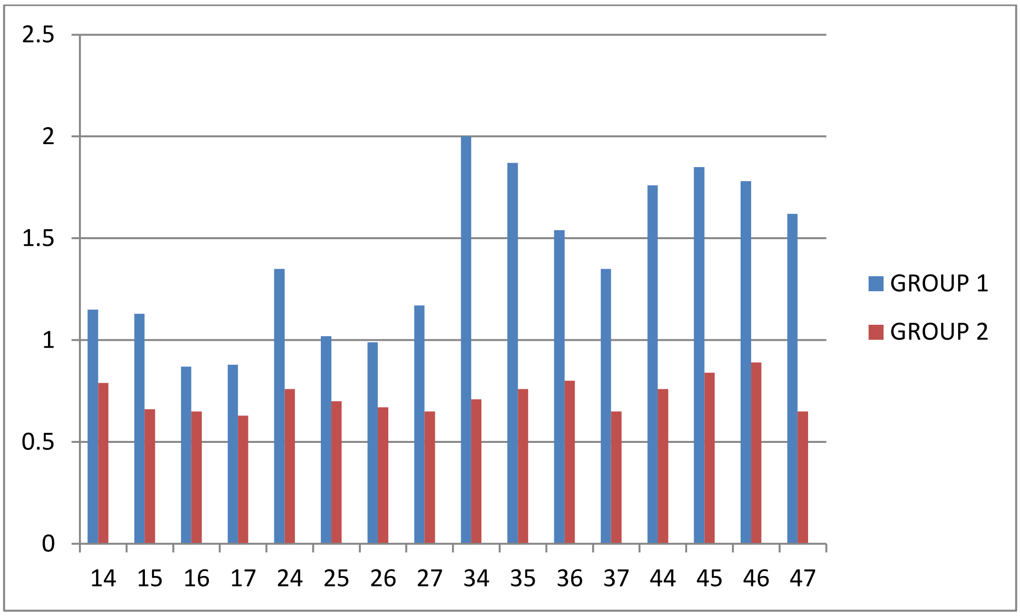
GRAPH 1: CLINICAL CROWN HEIGHT



GRAPH 2: MARGINAL RIDGE TO THE CENTRE OF THE BRACKET



GRAPH 3: MARGINAL RIDGE TO FACC



Discussion

DISCUSSION

In the past, the best clinical results were achieved by orthodontists who were considerably skilled at bending wires. However, with the development of preprogrammed brackets, i.e. the straight wire appliance system, clinical results depended solely upon accurate bracket positioning. Granted that definitive features like tip and torque were incorporated into preprogrammed brackets, expression of it depends on bracket positioning skill of the clinician.

The advent of indirect bonding improved the clinician's ability to position the brackets more accurately. Also, the introduction of light cured resins further improved the working time available to the clinician, permitting significant latitude in positioning the bracket before the resin is cured. Despite many products coming into the market; such as bracket positioning devices, newer adhesives, advanced light cure system, the **challenge** still remains with regard to **customized tray** fabrication for bracket positioning and the cost involved. Unpredictable nature of the previously used adhesive materials during bonding of the brackets on the cast was eliminated by a new technique by **Royce G Thomas**[66] that involved the formation of a custom base on the brackets.

An in-vitro study by **Richard A. Hocevar**[33] **in 1988** comparing bond strength and fracture location of brackets bonded with the indirect procedure as described by Thomas versus conventional direct bonding concluded that the indirect technique resulted in (1) Reduced amount of resin flash, (2) Diminished risk of voids that might weaken the bond and allow plaque accumulation, (3) Minimal adhesive thickness, (4) Sufficient bond strength, and (5) Easier cleanup after debonding.

The material used in the **present study to customize tray for bracket transfer** is a biocompatible 3D printing resin material for rigid splint (incisal or cuspal portion) which is rigid in nature, with better dimensional stability and transparency for the passage of light for curing. Gingival portion is made up of soft flexible material (tango+vero clear).

The indirect bonding technique allows for better three-dimensional visualization of tooth position, thereby resulting in greater precision while positioning brackets in the laboratory. The accurately placed brackets are transferred to the patient's mouth by means of custom-made trays. This benefit was confirmed by **Hodge et al**[34], who found that errors related with bracket positioning were minimized when indirect bonding was preferred over direct bonding with respect to height, angulation and mesiodistal position of brackets. Better hei ght positioning was also observed by **Koo et al**[46]**,** while **Aguirre et al**[1] highlighted the higher technical precision provided by indirect technique in terms of bracket angulation on maxillary and mandibular canines and height positioning on maxillary canines.

Other benefits associated with indirect bonding are: (1) reduced chair time, (2) little requirement for compensation bends, (3) reduced physical and mental pressure, since the clinical procedure is easier than direct bonding, and

(4) extra comfort for the patient. Drawbacks such as time-consuming laboratory procedures and additional costs with material are overcome by the formerly stated aids, which end up promulgating the technique. As a result of the increasing popularity of indirect bonding, new techniques have been developed. These techniques stand out especially on the bonding method applied (self or light curing) and the transfer tray used (hot glue, addition silicone, vacuum-formed, prototyped or associated methods). Despite the variety of techniques proposed, indirect bonding is not considered a gold standard procedure yet, certainly due to the numerous variables inherent to the process that need to be controlled if success is to be attained.

The indirect bonding technique should: (1) provide high accuracy in bracket placement and (2) be of simple execution. Achieving success with the described technique is not complex, provided attention is paid to the recommended details. It allows precise orthodontic appliance installation in one appointment, and can be used to place any bracket system commercially available.

Indirect bonding techniques were introduced to prevent the difficulties of inaccessibility and lengthy appointments while obtaining standard results, yet, the human factor in bracket placement cannot be overlooked. Many factors might affect the clinician's precision in bracket positioning. These include; years of experience, sharpness of sight, and manual dexterity.

The evolution of imaging techniques has opened new horizons for both diagnosis and treatment aid. Recent imaging techniques have allowed complete visualization of the tissues in three dimensions. Cone-beam computed tomography (CBCT) has proven to have great diagnostic value, with the ability to produce accurate images of the patient's soft and hard tissues. Along with that, it has advantages of examining the position of the root in relation to the crown while positioning the brackets aiming at accurate post-treatment root parallelism, which is considered essential for post-treatment stability[22].

Aim of the **present study** was to evaluate the accuracy of 3D bracket positioning with special consideration to root axes. The study involved 2 groups. In group A, 3D indirect-direct bonding was carried out and in group B, conventional direct bonding was done. The question was, is there any difference between accuracy of bracket positioning in 3D indirect and direct bonding?

In his previous study **Larry White**[49] used a small amount of aleene's Tacky Glue, to place the brackets on the casts instead of candy and other substances. The Thomas technique developed by **Royce G Thomas**[66] involving bracket bonding on to the study model by means of a light cured resin, thereby producing what was called a custom base light cured composite, was better than bonding with thermal cured composite employed by **Nanda, Sinha** and **Duncanson**[70]. The latter procedure involved heating the cast in a furnace for 30 minutes during which bracket float was commonly noted.

In the **present study**, a technique of indirect-direct bonding was utilized to **minimize** the time, armamentarium, and expenses needed for the preparation of models, trays, and positioning devices. Moreover, with this technique, brackets would be ready for bonding with **virgin bracket bases** not contaminated with resin or cast material, as was traditionally the case for conventional indirect bonding techniques. Remnants from the cast or excess resin on the bracket base might reduce bond strength or even disrupt the first-order position of the tooth because of the extra bonding material.

The transfer trays used in the previous studies by **Larry White**[49], **Arturo Fortini**[8] were quite rigid but also flexible enough to be removed from the tooth after bonding instead of individual trays which was time consuming.

For designing the splint in the **present study**, image of the stent was placed over the teeth and half of the brackets, leaving the other half of the brackets uncovered which prevented the bracket from locking in to the trays and allowed for easy removal even after bonding in patients mouth.

Larry white[47] used a self-etching primer and quick cure composite adhesive in indirect bonding. A power slot light-curing tip was used on each of the teeth in the tray for 3 seconds per tooth.

Similarly, **Arturo Fortini** and **Fabio-Giuntoli**[8] used a flowable composite as a bonding agent which allowed the excess material around the bracket base to be removed with a help of an ultrasonic scaler.

In the **present study** both direct and indirect bonding procedures were carried out using the light cured resin Transbond XT (3M Unitek). Transbond XT was preferred to other adhesives due to its superior strength as shown by **Bishara, Olsen** and **Von Weld**[79].

Since the development of CT, 3D imaging techniques have gained more applications in dentistry and orthodontics. The demand for the digitization, manipulation, and full use of the patient's virtual 3D model is increasing.

Whetten et al[78] investigated the difference between plaster models and the virtual 3D model (e-model) in treatment planning for Class II patients. He concluded that digital orthodontic study models (e-models) were a valid alternative to traditional plaster models in treatment planning.

OrthoCAD is a commercially available system that transforms casts or impressions into 3D digital models. Several studies have been conducted to compare 3D virtual models with plaster models. **Stevens et al**[74] compared various analysis on the gold-standard plaster model along with the digital counterpart, the e-model (GeoDigm), for tooth sizes and occlusal relationships, specifically the Bolton analysis and the peer assessment rating index. Strong agreement between the measurements indicated that the digital models were a good replacement for conventional plaster models.

The **present study** utilized 3D scanned digital cast model, to ensure dimensional accuracy of the 3D splint by super imposing the digital cast on to the abstracted CBCT images. The reason to compensate for problems relating to quality of the images produced by the CBCT when compared with advanced micro CT.

Over time, the concept of bracket positioning witnessed much development and innovation. Initially, **Angle**[6] showed that the most favorable position of the band was the position where it mechanically fits better and in the possible case bracket should be placed at the center of the labial surface of the tooth. After onward, the position of the band modified to the junction of the middle and the incisal third of the crown. In **Lawrence Andrews**[5] developed the bracketing technique of placing the straight guidelines of the bracket parallel to the long axis of the clinical crown. According to him, the "bracketing" process was almost always keyed to the buccal or labial surface of the crown. He considered the clinical crown as the usual clinical base or reference base that yielded uniformly constant bracket seating. But, as the buccal / labial crown surfaces differ in contours from one tooth type to another, he decided to take developmental ridges and grooves as common denominators as they are easily identified features common to all crowns at the same time not significantly subjected to environmental alterations such as chipping, wear and fracture.

When viewed from the bucco-labial perspective; for molars, the FACC is identified by the dominant vertical groove on the buccal surface. For all other teeth it is at the vertical mid-developmental ridge, the most prominent portion in the central area of the buccolabial surface. Viewed from mesiodistal perspective, the FACC is represented by a line tangent to the middle of the crown's labial or buccal surface. For molars it parallels the dominant groove and all other teeth, it parallels the mid-developmental ridge.

The FACC is far more practical for measuring and for other uses. No X-rays are necessary. This axis can be directly seen, touched, even marked with a pencil. So, **Andrews** chose the center of the clinical crown as a horizontal reference point and long axis of the clinical crown as vertical reference.

However, there are several ways in which bracket position can deviate from the ideal.

Horizontal errors: placing the bracket to the mesial or distal of the vertical long axis leads to unwanted tooth rotations. These errors can be circumvented by visualizing the vertical long axis; directly from the facial surface or with the mirror.

Vertical errors: improper vertical bracket placement can lead to intrusion or extrusion of teeth as well as to in-out and torque errors.

Paralleling errors: unwanted crown tipping can occur if the bracket wings are not parallel to the long axis.

Thickness errors: failing to confirm the base accurately to the tooth can cause improper torque or rotation or in-out. This problem can be overcome by expressing all excess adhesive from beneath the bracket during placement.

According to **Thurow**[77], two different vertical positions of a bracket on a tooth can cause two different buccolingual inclinations. **Mayer** and **Nelson**[54] had said that a vertical error by 3mm in bracket placement on a premolar can result in 15°torque alteration and in/out adjustment can alter by 0.04mm.**Angle (1928)**[6] to **Andrews (1970)** “straight wire concept”, there was great evolutions happened in the design of the bracket (tip, torque and rotation incorporated and bracket base thickness) to enhance the post treatment results. Even though, some authors (**Kraus,Tylor** and **Dellinger**[20]**)** found greater variations existed in the tooth morphology can negatively affect the treatment outcome.

In **1992 N.G.Taylor**[27] et al has done a study regarding the reliability of positioning preadjusted brackets, in which he emphasize that bracket angulation and inclination were found to be less reliable than either vertical or horizontal bracket positioning. On the same arena, previously **Andrews (1976)** has mentioned that operators could position brackets within 2° and 0.5 mm tolerable range of error for angles and linear positions of the bracket, respectively.

According to **Andreasen**[4], deviation in the mesiodistal bracket angulation can be calculated with the width of the arch wire used for the particular slot, it is of the order of 1° for central incisor and canines, when using a 0.019 inch width arch wire in an 0.022 inch bracket slot. Also, **Taylor** has mentioned that, in the clinical scenario, the effect of the deviation angle will be influenced not only by the geometry of the arch wire to bracket slot interface but also by archform and position of adjacent brackets on teeth.

Behalf of the above stated findings, unfavorable sequela can also happen if adjacent roots contacted. For example, in case of canine, excessive tip can exaggerate the apical displacements as the canine has long root.

Another problem encountered with the failure of attaining ideal bracket position is the variation in tooth morphology .Many studies has proven that interindividual variation in tooth morphology was a magnitude that left little reliance on the scientific basis of the straight wire philosophy.**Miethke** and

Melsen[62], his study encompassing interindividual variation in tooth morphology and change in first and third order control from bracket displacement, the foundation of the philosophy of preadjusted appliance can be rejected.

The technique of bracket positioning can be fraught with difficulties in (i) partially erupted teeth wherein the gingiva has not exposed the actual clinical crown, (ii) teeth surrounded by inflamed gingival tissue leading to foreshortening of the clinical crown; consequently bracket tends to be placed too incisally or occlusally, (iii) teeth with lingually or palatally displaced roots, gingival tissue covers a better portion of the crown and (iv) teeth with facially displaced roots (cuspids), clinical crown seems longer and bracket location will go too gingival.

Crown length concerns, like disproportionately long or short clinical crowns, can also deviate the bracket positioning from ideal. Incisal or occlusal concerns, such as patient with crown fractures or tooth wear, apparent clinical crown is smaller. This problem can be corrected by restoring the crown to its proper length. Crowns with long, tapered buccal cusps often do not have adequate contact with opposing teeth. In such cases, if the bracket is positioned in the midpoint of the clinical crown, the neighboring marginal ridges will not be aligned.

In order to reduce the difficulties associated with bracket positioning, **Alexander in 1983**[2,3] proposed the “vari-simplex discipline”. His philosophy was to ‘keep it simple’. The most important factors in determining the design of this system are the size and shape of the teeth, especially the mesiodistal width and curvature that affect the interbracket distance, which in turn affects the ability to rotate the tooth and level the arch without any extra wire bending. Accessibility of the tooth, whether it is located in a curved or straight area of the arch is the another major concern. He evolved the system around five factors related to brackets namely, (i) bracket selection, (ii) bracket height, (iii) bracket angulation, (iv) bracket torque and (v) bracket in-out, pertaining to different malocclusion and treatment modalities.

Height of the bracket is the one of the highly concerning factors of bracket positioning. Bracket height plays an important role in improving the clinical performance of the preadjusted appliances, because even a 1mm vertical deviation is enough to produce clinically significant changes in the torque (gingival displacement produces more expression of torque and incisal or occlusal displacement produces less expression of torque), in-out and marginal ridge leveling. Inversion of the bracket changes the torque value but the tip value is not changes[76].

Each bracket is placed at a predetermined position on each tooth relative to the other teeth. The bracket height affects the extent of torque and angulation and inciso-gingival position of the tooth. According to alexander discipline, bicuspid height, taken as ‘x’, is the key since its clinical crown height is so variable. Its average height is 4.5mm. Other bracket heights are calculated in relation to ‘x’.In upper arch ,X for central incisors ,X-0.5 for laterals,X+0.5 for cuspids, X for bicuspids,X-0.5 for first molars,X-1.0 for second molars. In lower arch, for centrals X-0.5,for laterals X-0.5, for cuspids X+0.5,for bicuspids X and for first molars X-0.5 accordingly .

In 1997, the MBT prescription was introduced. It rapidly established itself as one of the most prevalent bracket prescriptions in the market. The main modifications with other bracket prescriptions are:

- Palatal root torque is increased in the upper central incisor brackets (Andrews: 7°; Roth: 12°; MBT: 17°)
- Palatal root torque is increased in the upper lateral incisor brackets (Andrews: 3°; Roth: 8°; MBT:10°)
- lingual crown torque is increased in the lower incisor brackets (Andrews: -1; Roth: -1°; MBT: -6°)
- Tip in the upper canine brackets is decreased (Andrews: 11°; Roth: 13°; MBT: 8°).

The inventors of the MBT system claimed that the increased palatal root torque in the upper incisors improved the under-torqued appearance formed by other prescriptions. Likewise, the increased labial root torque in the lower incisor counteracted the forward tipping throughout levelling.

Mclaughlin[65] conducted 4 studies to establish the center of the clinical crowns. In evaluation of cases treated in accordance to Andrews's Six Keys, marks at the center of the clinical crowns consistently deviated from a straight line at the upper bicuspids, upper second molars, the lower cuspids and lower first molars. Bracket height of clinical cases at debonding was not found to be located in the center of the clinical crowns of all teeth. In the upper arch, the bracket height of the bicuspids were consistently 0.5mm greater than those found in the theoretical Bracket Placement Chart, and those of the second molars were 0.5 - 1mm less. In the lower arch, the bracket heights of the cuspids and first molars were consistently 0.5mm less than those found in the chart. The lower second molar bracket heights were either identical to those of the lower first molars, or in some cases 0.5mm more gingival. The minor variations found in these studies were incorporated in to theoretical bracket placement chart to produce a “recommended bracket placement chart”.

- Measure the clinical crown heights of as many fully erupted teeth as possible from the patient's study casts.
- Divide each measurement in half and round to the nearest 0.5mm to obtain the distance from the incisal or occlusal edge to the center of the clinical crown.
- Select the row in the bracket placement Chart that contains the greatest number of equal values.
- Position each bracket initially by visualizing the vertical long axis of the clinical crown as a vertical reference and the estimated center of the clinical crown as a horizontal reference.
- Use a bracket placement gauge to adjust the bracket heights to the exact values from the chart.

Mclaughlin stated that the use of a bracket placement chart (developed in 1994), as well as pre-adjusted Dougherty gauges, dramatically reduced bracket placement errors in the vertical dimension.

The **Damon system**[12] is a passive self ligation system that was originally introduced in 1994. Bracket positioning follows the principles suggested by Andrews where brackets are placed on the midpoint of the facial axis of the clinical crown with the vertical bracket positioning parallel to this axis with certain exceptions. The following exceptions are:

- Lower cuspid brackets should be positioned 0.5 mm to 1 mm mesial to the facial axis of the clinical crown to prevent the mesial edge of the cuspid tucking behind the distal part of the lower lateral incisor.
- For deep bite cases, cuspid and incisor brackets should be progressively placed slightly more incisally in both arches to aid bite opening.
- For open bite cases, cuspid and incisor brackets should be placed progressively slightly more gingivally in both arches to aid bite closure.
- For significant translation, over-angulation of the brackets to exaggerate the root movement in the desired direction will ensure adequate root movement.
- Teeth with incisal edge damage or teeth substituting for other teeth, the brackets are positioned to obtain the correct gingival emergence profile. The subsequent incisal edge problem is corrected restoratively.

Several studies have shown the variations in torque values of teeth achieved following treatment with pre-adjusted edgewise appliances (**Dellinger 1978, Ugur and Yukay 1997). Kattner and Schneider**[41] **(1993**) found no differences in the Ideal Tooth Relationship Index when they compared the study models of patients treated using a Roth prescription preadjusted edgewise appliance with those treated using a standard edgewise appliance.

Recently, **Thomas Pitts**[15] developed a new bracket positioning protocol called Smile Arc Protection bracket positioning, which supports today's esthetic philosophy of compensation for greater width in the upper posterior teeth, with minimal negative space in the buccal corridors. This esthetic concept also calls for optimal axial inclination of the upper anterior teeth, with incisor dominance and a curved smile arc of the upper incisal edges following the curvature of the lower lip in a posed smile.

To create a pleasing smile arc and positively affect the anterior portion of the upper occlusal plane cant, the maxillary anterior brackets are positioned more gingivally than in traditional techniques for smile arc protection. The maxillary arch wire plane is then parallel to the upper lip. The incisal edges of the upper anterior teeth will follow the lower lip with treatment. The divergence of the wire from the occlusal cusp tips or incisal edges increase from posterior to anterior. The greater the differential from the buccal segments to the anterior segment, the more the wire plane helps increase the **maxillary occlusal plane** cant in relation to the true Frankfort horizontal.

In the **present study**, MBT bracket prescription (3M MBT Gemini) was considered due to its better reliability in positioning technique and its current acceptance in the field of orthodontics.

To obtain the bracket's stereolithographic images, in the **present study, structured light scanning technique** has been used. The problems of trying to acquire dimensionally accurate images using structured light scanning methods have been reported by **Bibb et al**[11]**and Mah** and **Hatcher** .The light beam from structured light scanners travels in straight lines. Consequently any object surfaces that are hidden to the line of sight of the light source will not be scanned. This results in voids in the scanned surface date. To overcome this problem the object or scanner needs to be moved to different angulations and scan process repeated at each angle. For irregular object multiple scans of the same object from different angles may need to be acquired. Data from each of these scan can be then stitched together by using special software program to attain a well-defined image of the bracket for **digital indirect bonding**.

Three dimensional bracket positioning was done in the **present study** using **mimics software** for conversion (version20).Patient's digitally scanned cast and superimposed on the abstracted CBCT images. 5 reference planes took for bracket positioning, incisal or occlusal, mesial, distal, long axis (vertical), mesiodistal (horizontal).Then positioned the scanned bracket on each tooth according to the MBT bracket height chart and positioned accurately using the mimics software tools. Bracket positioning, planning and designing of splint was done with the help of **Geomagic freeform plus software**.

In orthodontic practice the application of 3D printing technology is increasing and there are large selections of 3D printers available that utilize many different printing technologies. By using these available technologies, digital files can be printed using ceramic, metal, wax and resin materials utilizing highly unique processes depending on which technology is utilized.

The most commonly used 3D printing technology in orthodontics is solid-based fused deposition modeling (FDM) , whereby liquid resin is built up as a solid object. Recently, different liquid-based 3D printing technologies such as stereolithography apparatus (SLA) and digital light processing (DLP), and PolyJet have been introduced. Ultra violet (UV) curable resin is polymerized to form the desired shape by light sources in these technologies.

Bibb et al[11]. compared two plaster models with their replicas created by stereolithographic 3D printing technology and he concluded that the mean difference in the vertical dimension was highly significant for the replica, probably because of the thick layers of clear resin (0.15 mm) from which it was built. **Hazeveld et al[32],** in his study compared the accuracy and reproducibility of physical dental models reconstructed from digital data by several rapid prototyping techniques and he concluded that the model reconstructed are considered clinically acceptable in terms of accuracy and reproducibility**. Kasparova et al[40]**. compared the qualities of two 3D printing options FDM and commercially available SLA 3D printing. They reported that the commercially available SLA 3D printing demonstrated more details than the FDM system.

The printing technology used in the **present study** is, **SLA (**machine-formlabs form2) for incisal portion and **polyjet (** Stratsays J750**)** for gingival portion . SLA utilizes an ultraviolet laser to cure a liquid polymer into solid resin and polyjet utilizes an array of ink-jet print heads to deposit liquid photopolymers onto a platform .Once the 3D printed tray received, brackets were transferred to the tray and bracket positioning has done in the patient's mouth directly.

Evaluation of bracket positioning was done using **photographic** method along with **cast models**. **Bon Chan Koo**, **Chung** and **Vanarsdall**[46] have suggested the photographic method is more reliable than mere clinical examination.

Aguire King and Waldron[1] suggested a jig made of 0.019 x 0.025 inch stainless steel wire to be attached to a tripod onto which the camera is attached. However, pilot studies show that the technique suggested by **Koo Chung** and **vanarsdall**[46] was equally accurate and using jig attached to tripod offered no distinct advantage over using a jig over the camera.

In the **present study** photographs were taken using canon 700-D camera with 100mm macro lens with 1:1 magnification and a jig secured on the camera is made of 0.019 x 0.025 inch rectangular stainless steel wire set at a distance of 150mm for standardization. All teeth to be evaluated were photographed individually.

By using the application called **ImageJ** all measurements were performed on the computer. All 5 variables, vertical height, mesiodistal measurement, long axis error, paralleling error, thickening error were checked in 280 teeth (84-indirect bonding, 196–direct bonding). The **statistical analysis** (non-parametric) used in the study is Mann Whitney utest (Software: spss ibm version 22) for the comparison between both groups. Mean errors calculated for each variables in both groups in all teeth individually and relative accuracy of bracket positioning between 2 techniques on all teeth was compared.

The result showed a statistically significant (< 0.05) difference between the indirect and direct bonding group. When comparing the precision in bracket placement between the two techniques on all teeth the indirect bonding technique showed superior to conventional direct bonding technique.

LINEAR MEASUREMENT:

In the **present study**, **Vertical bracket placement** in relation to 25(mean error in group A=0.256 and group B=0.878), 36 (mean error in group A=0.077and group B=.385), 37(mean error in group A=0.395 and group B=1.025), 41(mean error in group A=0.004and group B=0.655) and 43(mean error in group A=0.239 and group B=0.531) showed greater precision in bracket placement with indirect bonding.

Koo, Chung, and **Vanarsdall**[46] stated that indirect bonding technique provides better bracket placement with regard to bracket height than direct bonding, **in agreement** with the present study. **Jiyeon Kim**[42] used digital method to position the bracket using CAD/CAM system. In that study, he reported that differences in cusp height of maxillary posterior teeth did not produce a statistically significant difference in the linear, not concurring with the present study.

Horizontal error-in indirect bonding 31(mean error in group A=0.027 and group B=0.023), 33(mean error in group A=0.126 and group B=0.710),and 42(mean error in group A=0.133 and group B=0.514) showed improved bracket positioning in the **mesial** side. In the **distal** side 31(mean error in group A=0.023 and group B=0.283), 33(mean error in group A=0.144 and group B=0.710) and 42(mean error in group A=0.033 and group B=0.303) showed statistically significant difference.

In **Koo, Chung**, and **Vanarsdall's**[46] study there is **no** statistically significant difference result regarding the mesiodistal position of the bracket between the two techniques. Both bonding techniques showed similar bracket placement except lower left central incisor on which indirect was better, **not** in agreement with the present study.

ANGULAR MEASUREMENTS

In the **present study**, **long axis error** (long axis of the tooth with the long axis of the bracket) in relation to 16(mean error in group A=0.000 and group B=1.425), 33(mean error in group A=0.284 and group B=2.771) and 45(mean error in groupA=0.000 and groupB=3.335) yielded better results with indirect bonding technique.

Matthew Israel[35], in his study, noted that computer aided bracket positioning is significantly better at aligning the marginal ridges of the upper posterior segment but was significantly less successful at achieving proper alignment and buccolingual inclination of the upper first premolars and properly angulating the lower lateral incisors. **Aguirre, King** and **Waldron**[1] reported superior angular accuracy for the canines in indirect technique, **in agreement** with the present study. **Koo, Chung**[46] in their study found out that regarding the angular measurement there was no statistically significant difference between the two techniques on most teeth, except that direct bonding showed better bracket placement on upper right lateral incisor. **Jiyeon Kim**[42] in his study stated that there is no statistical difference in angular `dimensions of bracket placement with the CAD/CAM indirect bonding system, **not in concurrence** with the present study.

In the **present study paralleling error** (incisal plane with bracket base) results of 11(mean error in group A=0.082 and group B=2.957), 14(mean error in group A=0.269 and group B=1.609) and 16 (mean error in group A=.000 and group B=2.406) showed better bracket position in the indirect group.

Thickening error- This variable alone showed no statistical difference between both the groups. There is no previous study carried out with assessing thickening error.

When comparing all 5 variables, vertical measurements showed better precision with indirect bonding technique and thickening error alone showed no significant difference between the errors in both groups. **Mean total error** in the indirect bonding technique is (0.463) less when compared with the direct bonding technique (0.557). On the contrary, **T M Hodge**[34] had stated no statistically significant difference between mean bracket placement errors for direct or indirect methods even though the range of error in the three directions assessed was greater for direct technique.

Kyoung-Hui Son[71] established a new virtual orthodontic system for indirect bonding which enabled placement of the virtual brackets at the predetermined position using 3D models. He claimed that compared to the traditional method of manual set-up and fabrication of transfer tray, this new virtual orthodontic treatment system could optimize bracket positioning, reduce excessive laboratory burden and provide several treatment-planning options.

Deviating from other previous method of bracket positioning, in the **present study** patient CBCT were used for bracket positioning. This aided in the bracket positioning by considering the **root axis** of each tooth thereby, achieving a better bracket axial positioning to the tooth when compared to the direct method as well as the previous indirect bracket positioning methods.

Various studies have reported that bond strength can be vary in both direct as well as indirect bonding. In **1982**, **Michael J. Aguirre**[1] found that indirect bonding show a smaller percentage of failure than the direct bonding. This finding did not confirm that of **Zachrisson** and **Brobakke**[80].

Yi et al[28] found no significant difference in bond strength between indirectly bonded brackets with Transbond XT and Sondhi Rapid Set and a light-cured direct bonded control group. **Polat et al**[61] found no difference in bond strength between the light-cured direct bonded control and the Therma Cure protocol, whereas the bond strengths for the Sondhi protocol were significantly lower.

Linn et al[50] found no statistically significant difference in bond strength among the Sondhi protocol, a protocol using a light-cured composite (Enlight LV) with a light-cured sealant (Ortho Solo), and a direct bonded light-cured group.

In the **present study**, instead of bond failure rate, the **thickening errors** were tested to find out the probability of bond failure as well as the rotational like tooth movement errors that could occur due to the improper spreading of the underlining adhesives. The results showed that there is no statistically significant difference in case of thickening error in both direct as well as indirect method of bracket positioning.

Early studies have described that bracket positioning by the measurement method was more precise than center of the clinical crown. But few recent studies have showed that even the measurement method can also results failure of marginal ridge leveling. **Sergio Estelita Barros**[10], in his study, comparing the vertical changes of adjacent **marginal ridges** and centre of clinical crowns found no equivalence between them, denoting the clinical crown centre was not an accurate predictor of the marginal ridge leveling. According to the **American board of orthodontics** 'objective grading system, the grade is reduced when alignment and difference of marginal ridges are over 0.5mm.Which reinforces the clinical significance of three dimensional bracket positioning.

In the **present study** using 3D records (CBCT) for bracket positioning, by visualizing the entire tooth in the 3 dimensional spaces, the root angulation for better root parallelism as well as precise location of marginal ridge was achieved. Three parameters; total clinical crown height, marginal ridge to center of bracket and marginal ridge to FACC for all the posterior teeth were analyzed. In the study group, the bracket was more towards gingiva when measuring from the marginal ridge to center of the bracket when compared to the control group. This could be attributed to the use of 3D for the precise linear digital measurement for bracket positioning by considering the full tooth in all three planes, which was not allowed in the conventional direct bracket positioning method. For example the discrepancies between the each adjacent tooth (14-15,15-16,16-17) was found to be higher for premolars and lower for molars; which was in concurrence with the reduction in total clinical crown length as well as bracket vertical height. But the trending line varies with every individual, which has to be assessed properly and can be adjusted with positive or negative **coronoplasty.**

Irrespective of the method used for bracket positioning, there existed some margin of variation from the ideal location and was done before operator error was taken into account. Incorrectness were reported for premolars, when brackets were positioned at the FA point while taking measurements from the incisal edge leading to marginal ridge differences between the premolars and molars and absence of occlusal contacts with the opposing dentition (**Eliades et al[21]., 2005).**

In **2009, Carlos Suárezn[75]**, concerning the leveling of marginal ridges by bracket placement protocol with fixed values from the incisal edges and occlusal surfaces (digitized models), found that vertical bracket positioning protocols which ignore individual labial crown convexities and crown height may result in initial bracket placement error leading to poor marginal ridge levelling at the final stage of the treatment. He stated that computer simulations adjusting bracket heights to perfect marginal ridge relationships are possible and may lead to new height bracket placement protocols in the future.

Hence the importance of taking 3-dimensional records became a significant and integral part of the present study; using CBCT as the diagnostic record as well as to assist with bracket positioning. A digitized scanned model was also used so that all the factors could be taken in to consideration. Marginal error for marginal ridge alignment substantially decreased and was found to be clinically significant.

Influences of Indirect bonding technique in minimizing the plaque accumulation is an another concept ascends with the evolution of different indirect bonding technique. In a study conducted in **2012** by **Domenic Dalessandri[17]** has mentioned about the effectiveness of an indirect bonding technique in reducing plaque accumulation around braces and he concluded that the indirect bonding protocol allowed for a significant reduction in plaque accumulation around the braces during the first 4 months after bracket placement.

In these busy day to day life, time is becoming an essential factor for the clinician as well as for the patients.so reduction in the **time** taken for the treatment procedure has a major role in the clinical practice. **Jefferson Vinicius Bozelli et al**[36] has done a comparative study regarding the time length taken for bracket positioning in direct and indirect bonding and the results showed that the total time spent with the indirect bracket bonding (19.46 minutes) technique was shorter than direct bracket bonding (38.92minutes) technique, which is in agreement with the **present study**. In busy practice the indirect bonding procedure could deliver efficient bracket placement in considerably **less chair side time**, which overweighs the payment involved in the laboratory procedure.

The clinical implication of the errors in bracket positioning are unstable tooth position, lack of root paralleling, food impaction because of marginal ridge discrepancies and failure to establish the very specific occlusal scheme of canine rise or mutually protected occlusion.

From all these evidence, the **present study** can be concluded that accuracy of bracket positioning between direct bonding and 3D indirect bonding showed a clinically significant difference that speculate the hypothesis of the study.

LIMITATIONS

- Number of samples used in this study was less.
- The splint material used was a transparent, rigid, hard resin. A semi-flexible splint (hybrid) may perhaps aided easy removal of the tray after bracket bonding.
- Root apex relation was checked with regard to the bracket long axis in indirect method from the CBCT, but the same could not be done in direct bonding groups after bonding.
- As for the method of error assessment, instead of photos and models, Intra oral scanners may prove to be more accurate, as well as easy way of minimizing bracket errors.

Summary and Conclusion

SUMMARY AND CONCLUSION

Accurate bracket positioning is imperative for desired orthodontic treatment results. The **purpose** of this study was to evaluate the three-dimensional accuracy of bracket positioning using photographic images as well as models.

A total of 280 brackets were evaluated, including buccal tubes (84-study group, 196-control group).10 patients were selected by considering the inclusion and exclusion criteria. In STUDY group (A) CBCT was taken and three-dimensional bracket positioning done by using mimics software tools, indirect – direct bonding done. In CONTROL group (B) conventional direct bonding protocol followed. After bonding, photographs and models were taken for evaluating the bracket positioning in both groups. Five variables including vertical height, mesio-distal measurement, long axis, thickening error and paralleling error were statistically assessed using Mann Whitney U test. Total clinical crown height, marginal ridge to the center of bracket, marginal ridge to the FACC were examined and described through graphs in this study, were deemed and considered important features necessary for leveling and aligning of marginal ridges.

Therefore, the conclusion drawn from the present study are;

- Relative accuracy of the two techniques on all teeth is comparably better in relation to indirect bonding technique.
- In all 5 variables vertical measurements showed better precision with indirect bonding technique and thickening error showed no significant difference between both groups.
- Mean total error in the indirect bonding technique is (0.463) less when compared with the direct bonding technique (0.557).

The outcome of the present study reveals that the accuracy of bracket positioning using three-dimensional imaging techniques allow for precision in bracket placement with reduced clinical chair-side time when compared to the conventional bonding technique. Although cone beam computed tomographic imaging enables bracket positioning considering the root of the tooth. These findings need to be established in future studies with larger samples.

Hence, it can be concluded that the three-dimensional bracket positioning by using CBCT is a dependable indirect-direct bonding method.

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Annexures

Annexure – I

RAGAS DENTAL COLLEGE & HOSPITAL

(Unit of Ragas Educational Society)
Recognized by the Dental Council of India, New Delhi
Affiliated to The Tamilnadu Dr. M.G.R. Medical University, Chennai
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TO WHOM SO EVER IT MAY CONCERN

Date: 18-01-19

Chennai.

From,

The Institutional Review Board,

Ragas Dental College and Hospital,

Uthandi, Chennai-600119.

The Dissertation topic titled **"THREE DIMENSIONAL EVALUATION OF ACCURACY OF BRACKET POSITIONING "** submitted by **Dr.Amruthasree .M** has been approved by the Institutional Review Board of Ragas Dental College & Hospital.

Dr. N S Azhagarasan, M.D/S
Member Secretary,
Institutional Ethical Board,
Ragas Dental College and Hospital,
Uthandi, Chennai-600119.

Annexure – II

URKUND

Urkund Analysis Result

Analysed Document:	11 results.docx (D47625348)
Submitted:	2/5/2019 5:59:00 PM
Submitted By:	dramruthaunni@gmail.com
Significance:	3 %

Sources included in the report:

4 ABSTRACT.docx (D47625343)
9 MATERIALS AND METHODS.docx (D47625347)

Instances where selected sources appear:

4

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